8. PRAZGODOVINSKO LESENO KOLO Z OSJO S KOLIŠČA STARE GMAJNE NA LJUBLJANSKEM BARJU

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8. PREHISTORIC WOODEN WHEEL WITH AN AXLE FROM THE PILE-DWELLING STARE GMAJNE AT THE LJUBLJANSKO BARJE

Anton VELUŠČEK, Katarina ČUFAR & Martin ZUPANČIČ

Izvleček

Predstavljeno je prazgodovinsko leseno kolo z osjo s koliščarske naselbine Stare gmajne na Ljubljanskem barju, ki je bilo odkrito leta 2002. Analize kažejo, da gre za vrhunski tehniški izdelek prazgodovinskega kolarja. Glede na datiranje naselbine, kjer je bilo kolo najdeno, njegovo starost ocenjujemo na približno 5150 let.

Ključne besede: leseno kolo z osjo, predstavitev in datiranje, kolišče, Stare gmajne, Ljubljansko barje, 4. tisočletje pr. Kr.

Abstract

This chapter introduces a prehistoric wooden wheel with an axle discovered in 2002 at the pile-dwelling settlement Stare gmajne at the Ljubljansko barje. Analyses indicate that it was a technologically advanced product, manufactured by a prehistoric wheelwright. Considering its radiocarbon dating and the age of the settlement, where it was found, the wheel is c. 5150 years old.

Keywords: wooden wheel with an axle**,** presentation and dating, pile-dwelling, Stare gmajne, the Ljubljansko barje, 4th millennium BC.

8.1 UVOD

Ko se je ekipa Inštituta za arheologijo ZRC SAZU[1] v zgodnji pomladi leta 2002 podala na dokumentiranje in vzorčenje arheološkega lesa iz odvodnih jarkov na Starih gmajnah, si ni bilo mogoče niti v sanjah predstavljati, na kaj vse bomo naleteli. Najprej nas je nemalo presenetilo odkritje odlično ohranjenega drevaka v jarku 4 (*sl. 8.1*).

Ko smo najdbo dokumentirali in organizirali srečanje arheološke nadzorne komisije ter skupaj odločili, da drevak pustimo tam, kjer smo ga našli, smo v jarku 1 na skrajnem vzhodu odkritega dela naselbine (*sl. 8.1*) naleteli na še en drevak podobnega tipa kot prvi, le s to razliko, da je bil bolj poškodovan.[2]

Na Veliki petek 29. marca 2002, ko so bile naše misli že na krajših velikonočnih počitnicah, je sodelavec J. Dirjec slabih 20 m južno v istem jarku naletel na poškodovan kos lesa, ki je sprva spominjal na desko (*sl. 8.3*), po natančnejšem ogledu pa se je zdelo, da gre morda za pokrov lesenega soda,

[1] Arheološko ekipo so sestavljali: A. Velušček, J. Dirjec, B. Toškan in študent arheologije M. Turk.

2 Glej poglavje 9 v tem zborniku.

8.1 INTRODUCTION

When a team including members of the Institute of Archaeology of the Scientific Research Centre of the Slovenian Academy of Sciences and Arts (ZRC SAZU)[1] began documenting and sampling archaeological wood from drainage ditches at Stare gmajne in the early spring of 2002, it was impossible to imagine even in the wildest dreams, what we will discover. A discovery of an excellently preserved logboat in ditch 4 (*Fig. 8.1*) was the first surprise.

After the find was documented and the meeting with the archaeological supervisory committee was organised, we decided that the logboat should be left where found; in ditch 1, on the eastern most part of the settlement (*Fig. 8.1*), however, we immediately came across another logboat, similar to the first one, but in a worse state of preservation.[2]

On the Good Friday, 29th March 2002, when our thoughts were already directed towards the Easter holi-

[1] A. Velušček, J. Dirjec, B. Toškan and archaeology student M. Turk.

[2] See Chapter 9 in this monograph.

skratka za eno izmed novodobnih smeti, ki so jih odvodni jarki na Ljubljanskem barju še vedno prepolni.

Po Veliki noči, ko smo dokončevali dokumentiranje drevakov, je prišla na vrsto tudi obravnavana najdba. Po odstranitvi blata je sila teže najdbo odlepila od stene jarka. Takoj se je pokazalo, da gre za odkritje lesenega kolesa, ki je po možnosti tako staro kot naselbina, ki smo jo na podlagi tipologije keramike in prvih radiokarbonskih analiz lesa z drugih "sočasnih" najdišč datirali v sredo 4. tisočletja pr. Kr.[3]

Našo najdbo smo prepoznali kot kolo tudi zato, ker smo od obiska pri H. Schlichtherleju v Hemmenhofnu v Nemčiji pred nekaj leti že poznali najstarejša prazgodovinska lesena kolesa v Srednji Evropi. Neverjetna se nam je zdela le njegova domnevna starost, ki smo jo ob odkritju ocenjevali na približno 5500 let.

Odkritje kolesa z osjo na Starih gmajnah je doma in po svetu takoj zbudilo veliko strokovno in tudi laično zanimanje. Kmalu po odkritju je bilo pripravljenih nekaj poročil v domačih in tujih strokovnih revijah in zbornikih. Priprava besedila in slikovnega gradiva za prvo objavo je sledila samo nekaj dni po odkritju,[4] ko najdba niti še ni bila dobro očiščena.

Včasih se naglica izplača, v našem primeru pa se ni. V surovem, neočiščenem stanju se je namreč dozdevalo, da je kolo sestavljeno iz treh desk, kar smo tudi objavili in je bilo potem citirano v strokovni literaturi.[5] Napako, bolje rečeno prenagljenost, smo pri poznejših objavah popravili.[6] Upamo, da bo sčasoma izginila tudi iz strokovne literature.

S pričujočo objavo preiskav kolesa in osi torej izpolnjujemo naš dolg do strokovne pa tudi laične javnosti. Kot je razvidno v nadaljevanju, gre za predmet, ki je pravi tehniški biser prazgodovinskih mojstrov, čeprav predstavlja eno najstarejših lesenih najdb te vrste nasploh.[7]

8.2 ODKRITJE IN OKOLIŠČINE

Delno poškodovano prazgodovinsko kolo je ležalo v vzhodnem profilu jarka 1 v odseku 126, na meji z odsekom 125 (*sl. 8.1*).

Prvotno je bilo kolo nasajeno na os. Pri odstranjevanju plasti blata pa se je kolo z delom osi odlomilo, v prvotni legi je tako ostala glavnina osi, ki je štrlela iz vzhodne stene jarka (*sl. 8.4*). Dne 3. aprila 2002 je že omenjena ekipa Inštituta za arheologijo ZRC SAZU v smeri lesene osi zastavila manjšo sondo 1 (*sl. 8.2*). Pokazalo se je, da os leži pod kulturno plastjo v plasti gyttje (*sl. 8.5*).[8]

[3] Glej Veluščček 2001.
[4] Veluščček 2002a; 2002b.
[5] Npr. Pare 2006, 53, sl. 5.
[6] Veluščček 2006c.
[7] Prim. z Bakker et al. 1999; Voosten 1999; Ruoff, Jacomet 2002; Ruoff 2006.
[8] Glej poglavje 3.1.2.1 v tem zborniku.

days, our co-worker J. Dirjec stumbled upon a damaged piece of wood in the same ditch, some 20 m southward of the second logboat. It reminded of a plank at first (*Fig. 8.3*), a lid of a wooden barrel perhaps, i.e. modern rubbish, which can still be found in abundance in the Ljubljansko barje drainage ditches.

After Easter, when we were finishing with documenting of logboats, we also needed to document this find. After the removal of mud, the gravity force detached the find from the wall of the ditch. It turned out that it is a wooden wheel, perhaps as old as the settlement itself, which was, according to typology of pottery and the radiocarbon analyses of wood derived from other "contemporary" sites, dated to the middle of the 4th millennium BC.[3]

We visited H. Schlichtherle in Hemmenhofen in Germany a few years ago and were therefore familiar with the oldest prehistoric wooden wheels in Central Europe. We identified this find as a wheel. However, its presumed age seemed unbelievable, as we assessed it to be c. 5500 years old.

The discovery of the wheel with an axle at Stare gmajne immediately evoked amateur and scientific interest in Slovenia and across the globe. Soon after the discovery, several reports in local and foreign specialist journals and proceedings were published. Text and images were prepared only a few days after the discovery,[4] when the find has not yet been entirely cleaned.

Haste sometimes pays off, but not in this case. Raw, uncleaned condition of the find made us suspect that the wheel has been made of three planks. We published this observation and it was later quoted in scientific literature.[5] An error or precipitation was corrected in later publications.[6] We hope that the error mentioned will disappear from scientific literature in time.

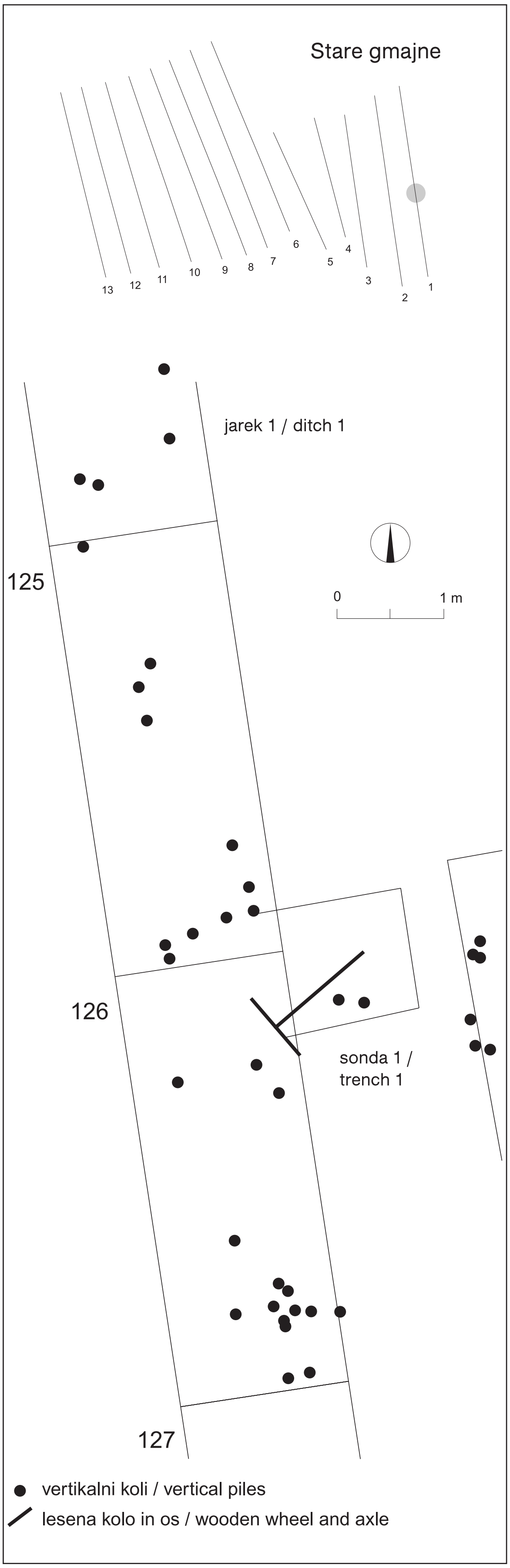
With this publication of investigations of the wheel and its axle, we pay our debt to scientific and popular archaeology. As we shall see, this object is a real technical gem made by prehistoric masters, although it is one of the oldest wooden finds of this kind.[7]

8.2 DISCOVERY AND CIRCUMSTANCES

Somewhat damaged prehistoric wheel was discovered in the eastern profile of ditch 1 in section/sector 126, right on the edge of section 125 (*Fig. 8.1*).

The wheel was fixed onto the axle at first. Upon removing a layer of mud, the wheel fell off; the majority

[3] See Veluščček 2001.
[4] Veluščček 2002a; 2002b.
[5] E.g. Pare 2006, 53, Fig. 5.
[6] Veluščček 2006c.
[7] E.g. Bakker et al. 1999; Vosteen 1999; Rouff, Jacomet 2002; Ruoff 2006.



Sl. 8.1: Načrt raziskanih odvodnih jarkov 1–13 na najdišču Stare gmajne s podrobnejšim prikazom razmer v jarku 1 ob sondi 1. Risba: T. Korošec.
Fig. 8.1: Plan of investigated irrigation ditches 1–13 at the site Stare gmajne, with details of ditch 1, adjacent to trench 1. Drawn by: T. Korošec.

Sl. 8.2: Sonda 1 v vzhodni steni jarka 1, med izkopavanjem. Foto: M. Turk.
Fig. 8.2: Trench 1 in eastern profile of ditch 1, during excavation. Photo: M. Turk.

of the axle stayed in its primary position, i.e. jutting out of the eastern profile of the ditch (*Fig. 8.4*). On the 3rd April 2002, a small trench 1 was opened in the direction of the wooden axle (*Fig. 8.2*). It turned out, that the axle was positioned under a cultural layer, in layer of gyttia (*Fig. 8.5*).[8]

8.3 DESCRIPTION OF THE FIND

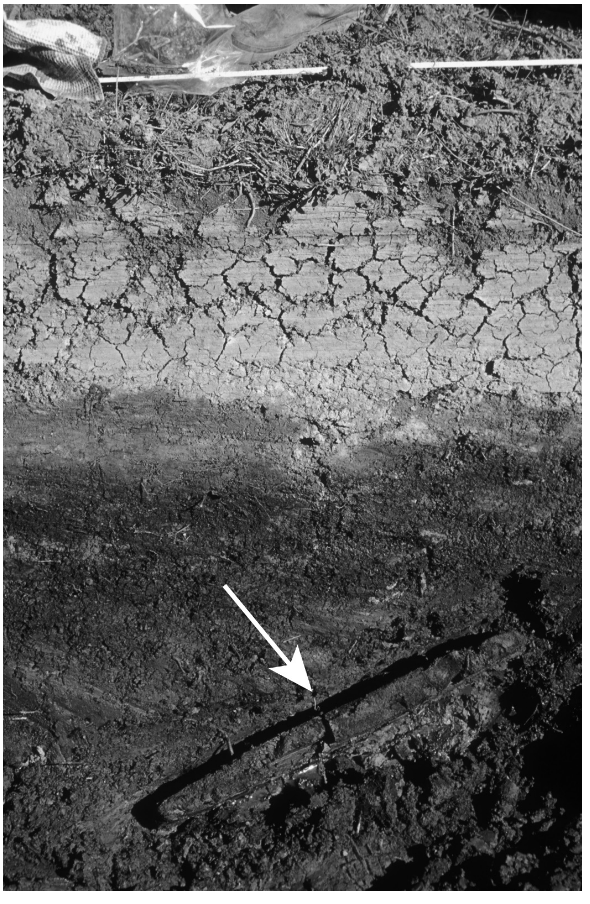
8.3.1 WOODEN WHEEL

8.3.1.1 THE DISC AND BATTENS

A wheel is a circular device capable of rotating on its axis. When a wheel forms part of a vehicle, generally the force of rolling resistance is less than that associated with kinetic friction. Therefore, only a small amount of effort is necessary to move the vehicle. Wheel is usually fixed to an axle, which rotates the wheel. The earliest and the simplest wheels, used for wheeled vehicles, were single-piece disc wheels with a central opening for the hub.[9]

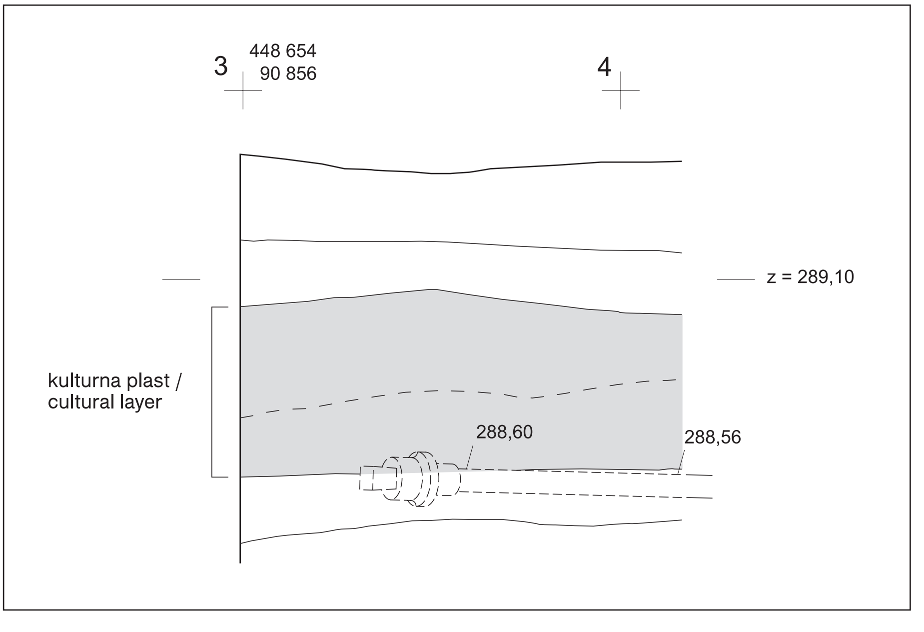
It is not yet known where wheeled vehicle was invented. Several theories exist.[10] It was perhaps invented in Mesopotamia,[11] contemporary in Mesopotamia and

[8] See Chapter 3.1.2.1 in this monograph.
[9] Piggott 1983; Vosteen 1999.
[10] E.g. Péterquin, Péterquin, Bailly 2006, Fig. 4; Hartmann 2006, 71–93.
[11] E.g. Sherratt 2006.

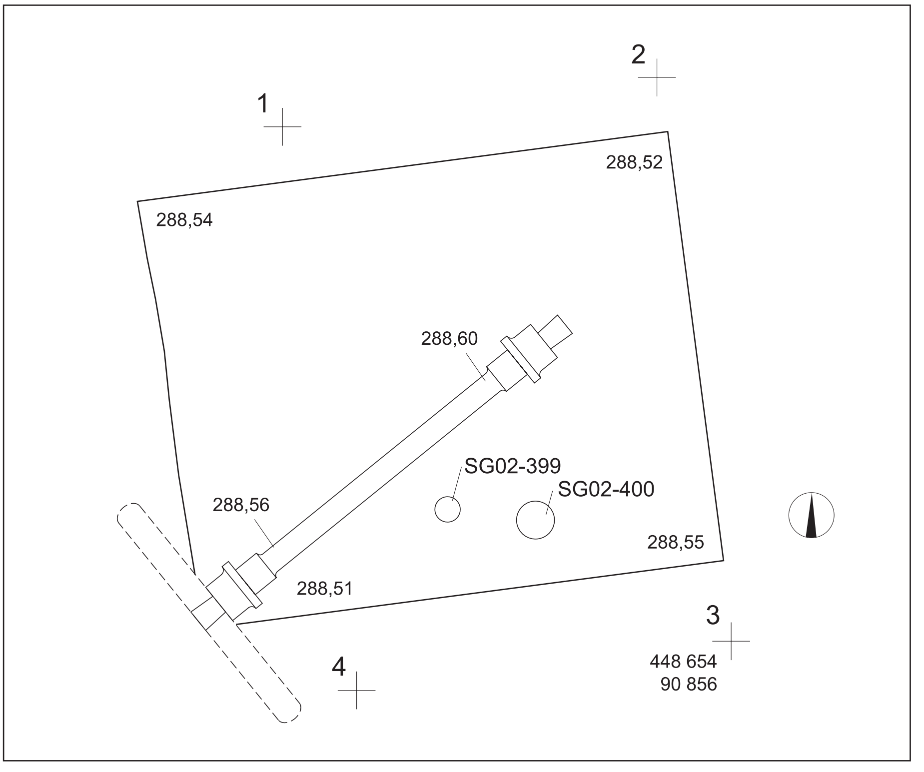


Sl. 8.3: S kmetijskim strojem poškodovano kolo *in situ* (puščica) na dnu v vzhodnem profilu jarka 1. Foto: M. Turk.
Fig. 8.3: Wheel, damaged by JCB, *in situ* (shown with arrow) at the base of the eastern profile of ditch 1. Photo: M. Turk.

Sl. 8.4: Os na strani A1 (oznaka s *sl. 8.21–8.23*) *in situ* z vidnim ležiščem kolesa. Foto: M. Turk.
Fig. 8.4: Axle, side A1 (see *Fig. 8.21–8.23*), *in situ*, with visible wheel bed. Photo: M. Turk.



Sl. 8.5: Južni profil sonde 1 s projekcijo osi na profil. Risba: T. Korošec. M = 1 : 20.
Fig. 8.5: Southern profile of ditch 1 with projection of the axle. Drawn by: T. Korošec. Scale = 1 : 20.



Sl. 8.6: Os v sondi 1 z obrisom kolesa v prvotni legi. Risba: T. Korošec. M = 1 : 20.
Fig. 8.6: Axle in ditch 1 with an outline of the wheel in its primary position. Drawn by: T. Korošec. Scale = 1 : 20.

8.3 OPIS NAJDBE

8.3.1 LESENO KOLO

8.3.1.1 DISK IN GREBENASTE LETVE

Po definiciji je kolo naprava okrogle oblike, ki z vrtenjem omogoa premikanje. Kadar je kolo del vozila, pri njegovem premikanju po podlagi nastaja kotalno trenje, ki je precej manjše od drsnega, zaradi esar je potrebna relativno majhna sila za premikanje. Kolo je navadno nasajeno na pogonsko os, ki prenaša vrtenje. V svoji prvotni in najpreprostejši obliki je bilo kolo vozil poln lesen kolut oz. disk, z odprtino v sredini.[9]

Območje iznajdbe vozila na kolesih še ni ugotovljeno. Obstaja več teorij.[10] Po prvi naj bi ga izumili v Mezopotamiji,[11] po drugi neodvisno in sočasno kot v Mezopotamiji tudi v Evropi,[12] po tretji pa najprej v Evropi.[13] Raziskovalci so si edini, da se je to zgodilo v 4. tisočletju pr. Kr.[14]

[9] Piggott 1983; Vosteen 1999.
[10] Npr. Pétrequin, Pétrequin, Bailly 2006, sl. 4; Hartmann 2006, 71–93.
[11] Npr. Sherratt 2006.
[12] Npr. Vosteen 2006.
[13] Npr. Matuschik 2006.
[14] Glej npr. Hartmann 2006, 90.

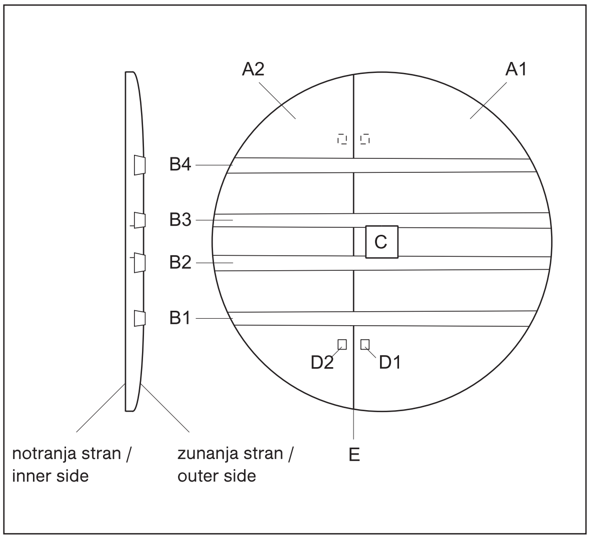
Europe independently from one another,[12] or in Europe.[13] However, general opinion is that the invention occurred in the 4th millennium BC.[14]

The prehistoric wheel from Stare gmajne was made as a disc with a rectangular central opening for the hub. The disc was made of two (A1 and A2) planks joined (tongue-and-groove joint) with four battens (B1–B4).

Planks are made of ash (*Fraxinus excelsior*) with wide annual rings, of trunk of over 40 cm in diameter and over 80 years old. The trunk belonged to a large tree; unlike trunks used for vertical piles in settlements, which had c. 10 cm in diameter. They used the same trunk to make both wheel planks (A1 and A2). A1 was closer to the pith, but it did not contain the pith and annual rings next to it (*Fig. 8.13*). It was radially oriented. Plank A2 was cut further away from the pith, and that is why at its radial orientation gradually turns to tangential. They followed a general rule, according to which radial planks without the pith and juvenile wood around it are dimensionally the most stable. Central part of a trunk (containing the pith and juvenile wood), which was not used, is generally considered as low-grade wood (*Fig. 8.12*).

[12] E.g. Vosteen 2006.
[13] E.g. Mautschik 2006.
[14] See e.g. Hartmann 2006, 90.

Sl. 8.7: Lesena os v sondi 1 *in situ*. Foto: A. Velušček.
Fig. 8.7: Wooden axle in ditch 1 *in situ*. Photo: A. Velušček.



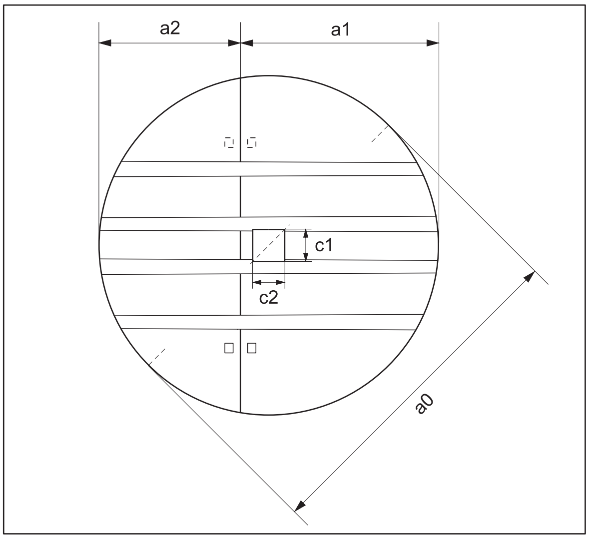
Sl. 8.8: Oznake delov kolesa:
- A1 in A2: kolesni deski
- B1 do B4: grebenaste letve
- C: pesto
- D1 in D2: odprtini v deski
- E: stik med kolesnima deskama.

Risba: T. Korošec.

Fig. 8.8: Parts of the wheel:
- A1 and A2: wheel planks
- B1 to B4: battens
- C: hub
- D1 and D2: openings in plank
- E: joint between wheel planks.

Drawn by: T. Korošec.

Sl. 8.10 / Fig. 8.10
Sl. 8.11 / Fig. 8.11



Sl. 8.9: Dimenzije kolesa in njegovih delov:
- premer: a0 = 71,2 cm
- širina deske A1: a1 = 41,6 cm
- širina deske A2: a2 = 29,6 cm
- širina pesta: c1 = 5,8 cm
- širina pesta: c2 = 6,8 cm
- debelina kolesa: na najdebelejšem osrednjem delu = ~ 6 cm.

Risba: T. Korošec.

Fig. 8.9: Dimensions of the wheel and its parts:
Dimensions of the wheel:
- diameter: a0 = 71.2 cm
- width of plank A1: a1 = 41.6 cm
- width of plank A2: a2 = 29.6 cm
- width of hub: c1 = 5.8 cm
- width of hub: c2 = 6.8 cm
- thickness of the wheel: thickest central part = ~ 6 cm.

Drawn by: T. Korošec.

Prazgodovinsko kolo s Starih gmajn je bilo narejeno kot poln disk z odprtino štirikotne oblike na sredini. Disk je bil sestavljen iz dveh desk (A1 in A2), ki sta širinsko spojeni (topi spoj) s štirimi grebenastimi letvami (B1–B4).

Deski sta iz lesa jesena (*Fraxinus excelsior*) s širokimi branikami iz debla premera nad 40 cm in starosti nad 80 let. Deblo je bilo iz drevesa večjih dimenzij, za razliko od debel, ki so jih uporabljali za vertikalne kole bivališč, za katere so bili najbolj zaželeni premeri okoli 10 cm. Iz istega debla so torej izdelali dve deski za obe polovici kolesa (A1 in A2). A1 je bila bliže strženu, vendar ni vsebovala stržena in branik neposredno ob njem (*sl. 8.13*). Bila je radialno orientirana. Deska A2 je bila v drevesu bolj oddaljena od stržena, zato pri njej radialna orientacija prehaja v tangencialno. Pri tem so upoštevali splošno znano pravilo, po katerem so dimenzijsko najstabilnejše radialne deske brez stržena in juvenilnega lesa okoli njega. Osrednji del debla, ki tu ni bil vključen, tudi sicer praviloma vsebuje les slabših lastnosti (*sl. 8.12*).

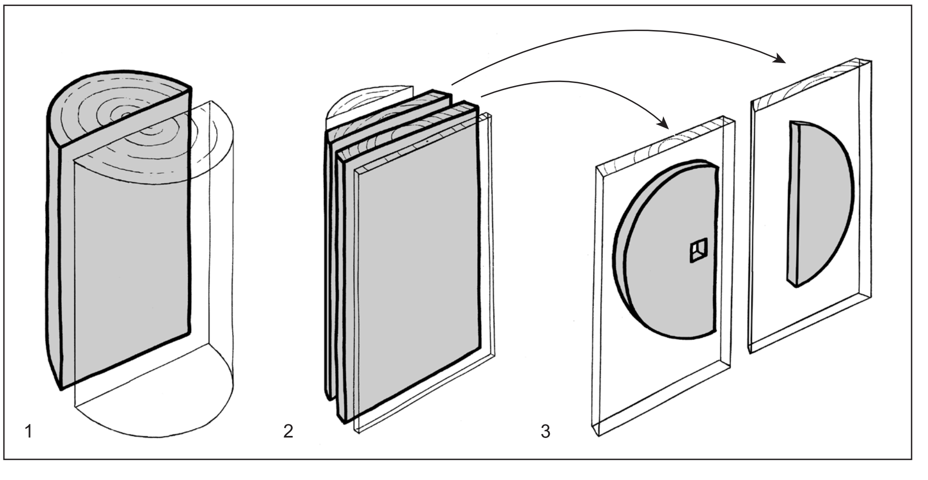
Glede na razpoložljivo prazgodovinsko tehnologijo so desko iz debla zelo verjetno izdelali s cepljenjem (klanjem) in tesanjem, saj kovinske žage, ki bi bila primerna za takšno opravilo, v 4. tisočletju pr. Kr. naj še ne bi poznali.[15] Za izdelavo kolesa so potrebovali približno 80 cm dolg kos hloda z lesom brez rastnih napak. Iz njega so nato odcepili dve deski debeline nad 6 cm (*sl. 8.13*). Ker je kolo izdelano iz dveh desk (A1 in A2), je bila pomembna obdelava robov, saj so ju širinsko topo spojili. Nato so izdelali štiri lastovičje utore trapezoidne oblike, ki so se izmenoma nekoliko ožali od leve proti desni oz. od desne proti levi (*sl. 8.10b, 8.11b*). Tako so se izmenjavali utori, ki so imeli ožji del na levi in desni strani.

[15] F. M. Feldhaus, Die Säge, 1921, v: *http://www.sbg.at/sendlhofer/geschichte/geschichte.htm;* Stappel 2007.

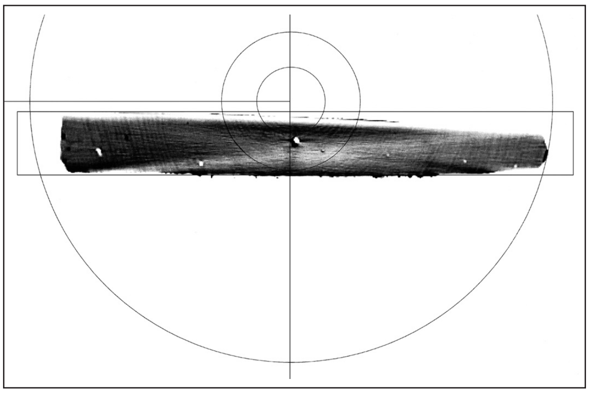
Sl. 8.12: Prečni prerez jesenovega debla. Osrednjemu delu, ki je na sliki temno obarvan in razpokan, so se pri izdelavi kolesa izognili, saj praviloma vsebuje les slabših lastnosti. Foto: M. Zupančič.
Fig. 8.12: Ash trunk; cross-section. The central part, which is darker and checked, was not used for making the wheel, as it generally contains low-grade wood. Photo: M. Zupančič.

Considering the available prehistoric technology, the plank was most probably made by splitting (cleaving) and hewing, as metal saws, suitable for such task, were not known in the 4th millennium BC.[15] C. 80 cm long piece of logwood without growth anomalies was needed for making the wheel. Two planks over 6 cm thick were then (*Fig. 8.13*) split off the log. As the wheel has been made of two planks (A1 and A2), the handling of edges was important, because they were horizontally tongue-and-groove spliced. Then four trapezoidal-shaped dovetail grooves were made, alternating in narrowness from left to right or from right to left (*Figs. 8.10b, 8.11b*).

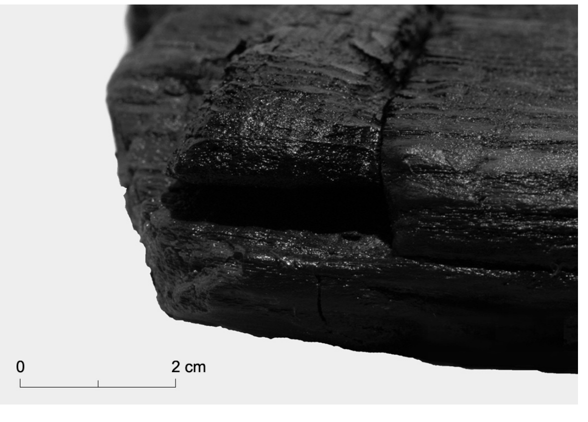
[15] F.M. Feldhaus, Die Säge, 1921, in: *http://www.sbg.at/sendlhofer/geschichte/geschichte.htm;* Stappel 2007.



Sl. 8.13: Položaj desk za izdelavo kolesa v deblu (1, 2) in položaj kolesnih desk A1 in A2 v radialnih deskah (3). Risbe: T. Korošec.
Fig. 8.13: Position of planks used for making a wheel in log (1, 2) and position of the wheel planks A1 and A2 in radial boards (3). Drawn by: T. Korošec.



Sl. 8.14: CT kolesne deske A1, kjer so vidne branike. Pripravil: M. Pflaum.
Fig. 8.14: CT of the wheel plank A1 with visible annual rings. Prepared by: M. Pflaum.



Sl. 8.16: Pogled na grebenasto letev B3, kjer je viden potek branik pravokotno na kolesno desko A2. Foto: M. Zaplatil.
Fig. 8.16: Batten B3 with visible annual rings running vertically to the wheel plank A2. Photo: M. Zaplatil.

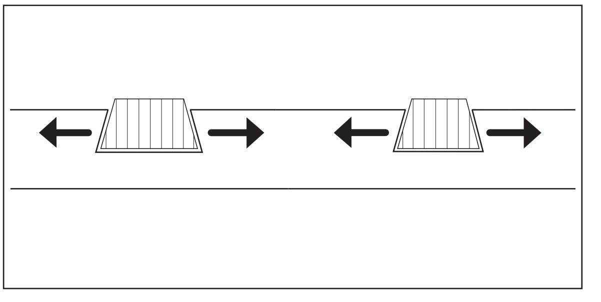
V utore so zabili enakomerno široke letve, ki so se v ožjem delu utora zagozdile. Tako izdelana lastovičja vez je omogočila, da sta bili deski trdno spojeni navkljub pričakovanemu krčenju in nabrekanju lesa.

Vloga štirih grebenastih hrastovih letev (B1–B4) (*sl. 8.10b, 8.11b*) je torej povezovanje desk. Od kakovosti izdelave utorov in letev, njihovega prileganja in namestitve je odvisna tudi trdnost kolesa.

Letve so v preseku izdelane v obliki t. i. lastovičjega repa (*sl. 8.15*), po dolžini pa v konus. To pomeni, da sta na isti deski konca sosednjih grebenastih letev izmenično pahljačasto koničasta oz. koničasto pahljačasta (*sl. 8.10b, 8.11b*).

Ni natančno znano, ali so morda obe deski pred izdelavo utorov začasno pritrdili skupaj in ali so pri tem uporabili luknji ovalne oblike: D1 in D2, ki ju najdemo na obeh deskah (*sl. 8.10, 8.11*). Prvotno so verjetno bile štiri take odprtine (glej *sl. 8.8*). Po mnenju J. Samsa, ki je

Sl. 8.15: Grebenasti letvi B1 in B2 s presekom v obliki t. i. lastovičjega repa na kolesni deski A2. Foto: M. Turk.
Fig. 8.15: Battens B1 and B2 with cross-sections in the shape of a so-called dovetail on the wheel plank A2. Photo: M. Turk.



Sl. 8.17: Radialno orientirane grebenaste letve v kolesu (branike v letvah na sliki potekajo navpično). Nabrekanje (in krčenje) lesa v smeri puščic je tako manjše, kot če bi bil les orientiran tangencialno. Risba: T. Korošec.
Fig. 8.17: Radially oriented battens in the wheel (batten's annual rings running vertically). Swelling (and shrinkage) of wood in the direction of the arrows is smaller as it would be if oriented tangentially. Drawn by: T. Korošec.

As a result, grooves with narrower left and right sides were alternating.

Evenly wide battens that served as tongues were then fitted into the grooves. They were wedged into narrower parts of grooves. Dovetail grooves allowed solid splicing of the planks, in spite of expected shrinkage and swelling of wood.

The function of the four oak battens (B1–B4) (*Figs. 8.10b, 8.11b*) was linking the planks. Moreover, strength of the wheel depends upon the quality of making of grooves and battens, of fitting and insertion of them.

Battens are of a so-called dovetail (*Fig. 8.15*) shape in cross-section and cone-shaped longitudinally; i.e. ends of adjoining battens are alternately fanlike-pointed or pointed-fanlike on the same plank (*Figs. 8.10b, 8.11b*).

It is not known for certain if the two planks were temporary attached to one another before making the grooves and if the two oval shaped holes, D1 and D2 izdelal kopijo kolesa in osi, so luknje verjetno rabili samo pri izdelavi kolesa. Zaradi potrebe po čim natančnejšem prileganju grebenastih letev in utorov je bilo najprej treba natančno in v ravni liniji speljati utore čez obe deski. Da je prazgodovinski kolar pri delu lahko dosegel takšno natančnost, je pred tem moral deski povezati, kar je verjetno naredil s pomočjo štirih lukenj, skozi katere je speljal povezovalni element rastlinskega ali živalskega izvora. Na Starih gmajnah smo v neposredni bližini kolesa, v sondi 2, npr. našli ostanke preje rastlinskega izvora, ki bi lahko služila tudi za izdelavo vrvi.[16] Po vstavitvi grebenastih letev v utore ni bilo več potrebe po dodatnem učvrščevanju, zato ob odkritju v kolesu ni bilo ostankov vrvi ali podobnega materiala.

Grebenaste letve so bile izdelane iz hrastovega lesa trapezoidne oblike in radialno orientirane, tako da je bilo krčenje in nabrekanje letev po njihovi širini minimalno (*sl. 8.17*). Utori in letve so bili zelo skrbno izdelani, tako da je bilo prileganje izredno natančno.

Kolo je imelo obliko diska, ki je bil na najdebelejšem osrednjem delu debel približno 6 cm. Ker je bilo iz masivnega lesa, je tehtalo več kot 20 kg, saj znaša gostota zračno suhega jesenovega lesa okoli 700 kg/m^3.[17] Z večanjem debeline bi sicer lahko dosegli še večjo trdnost, ki bi bila zaželena, hkrati pa bi bilo kolo tudi težje, kar ni bilo zaželeno. Z diskasto obliko, deski sta bili debelejši na sredini in zožani proti robu, so tako verjetno dosegli kompromis med trdnostjo in maso.

Z orientacijo lesa, kolo je bilo izdelano iz radialnih desk brez stržena in juvenilnega lesa, so izdelali kolesno desko, ki je izkazovala najmanjše možno krčenje po širini (*sl. 8.14, 8.18–8.20*). Če bi bila jesenova deska v deblu orientirana tangencialno, bi bilo krčenje precej večje, saj znaša totalni skrček od napojenega do absolutno suhega stanja lesa v tangencialni smeri 7 %, v radialni pa 4,5 % oz. se les glede na podatke o diferencialnem nabreku (q) ob spremembi vlažnosti lesa za 1 % skrči v tangencialni smeri za 0,38 %, v radialni pa za 0,21 %.[18]

Izbor lesa za kolo je bil zelo smiseln, saj je jesenov les zelo žilav oz. ima veliko dinamično trdnost, ki je potrebna za izdelek, kot je kolo. Jesenovega lesa je bilo v bližini kolišč dovolj.[19] Pomembno je tudi, da jesen lahko zraste v veliko drevo, saj so za desko potrebovali drevo z deblom brez grč in premerom nad 40 cm. Lastnosti lesa, tudi gostota in trdnost, so pri posamezni lesni vrsti variabilne, zato so pri izbiri pomembne tudi značilnosti posameznega kosa lesa in njegove orientacije. Pri jesenu je najtrdnejši les širših branik.[20] Prav take so bile branike

[16] Glej poglavje 15 v tem zborniku in tam navedeno literaturo.

[17] H. G. Richter in M. Oelker, INTKEY MACROHOLZDATA: Innovative digital tool for macroscopic wood identification and information retrieval for educational facilities and professionals in wood industry and trade: Computer programme; 2002 in dalje.

[18] Glej op. 17.

[19] Glej npr. Culiberg, Šercelj 1991 in poglavje 7 v tem zborniku.

[20] Čufar 2006.

(*Figs. 8.10, 8.11*), present on both planks, were used for this. Most likely, four such openings existed primarily (see *Fig. 8.8*). According to J. Samsa, who made a replica of the wheel and its axle, they probably needed these holes only while making the wheel. Accurate fixing of battens and grooves required precisely levelled grooves on both planks. In order to achieve such accuracy, the prehistoric wheelwright had to first fasten the planks to one another. This was probably done with the help of four holes through which a connecting element of vegetal or animal origin was tied. Remains of yarn of vegetal origin were found in direct vicinity of the wheel, in trench 2. It could perhaps be used for making a rope.[16] There was no need for additional fitting after battens were fitted into grooves. This is perhaps the reason why remains of rope or similar material were not found next to the wheel.

Battens were made of oak wood. They were of a trapezoid shape and radially oriented in order to achieve minimal shrinkage and swelling (*Fig. 8.17*). Grooves and battens were made very carefully and affixing was extremely accurate.

The wheel was disc-shaped and c. 6 cm thick in its central part. It was made of massive wood and therefore weighing over 20 kg, as the density of dry ash wood is c. 700 kg/m^3.[17] If thicker, the wheel could be even stronger. However, it would also be heavier. With its disc shape; planks were thicker in the centre and thinning towards the rim; they probably achieved a compromise between the wheel's strength and weight.

The wheel was made of radial planks without the pith and juvenile wood. They achieved minimal contraction of planks with radial orientation (*Figs. 8.14, 8.18–8.20*). If ash plank would be oriented tangentially, contraction would be higher, as the total shrinkage from water saturated to oven dry condition of wood amounts 7 % tangentially and only 4.5 % radially. Moreover, considering data of differential swelling (q) at 1 % change of moisture content of wood, ash wood shrinks 0.38 % tangentially and 0.21 % radially.[18]

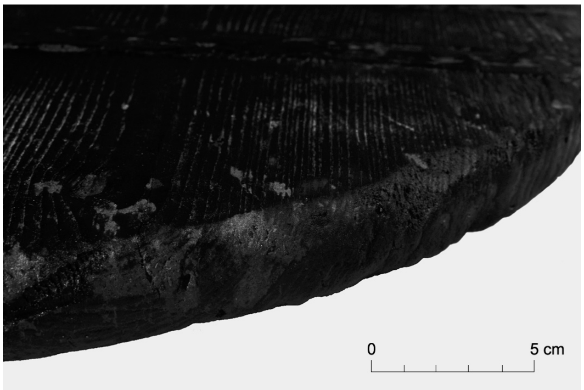
Selection of wood was very rational as ash wood is very tough, i.e. it has high impact strength, which is necessary for a product such as a wheel. There was enough ash wood near pile-dwellings.[19] It is also important that ash trees can grow big, because they needed a tree with a trunk without knots and with a diameter of over 40 cm. Characteristics of wood, its density and strength vary within an individual wood species. That is

[16] See Chapter 15 in this monograph and there cited bibliography.

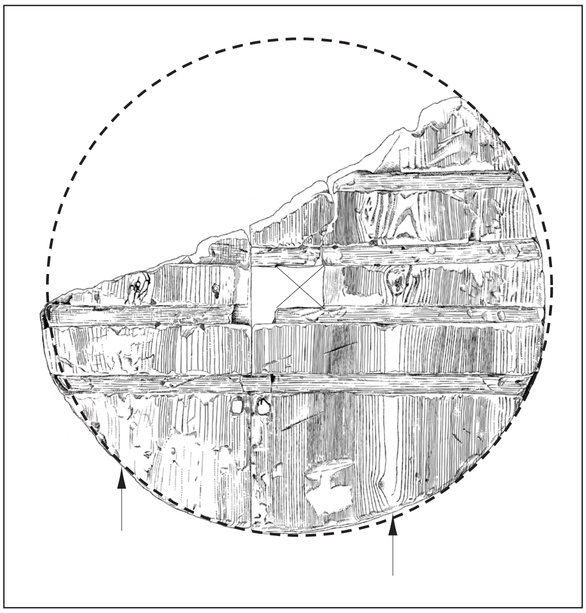
[17] H. G. Richter in M. Oelker, INTKEY MACROHOLZDATA: Innovative digital tool for macroscopic wood identification and information retrieval for educational facilities and professionals in wood industry and trade: Computer programme – 2002, onwards.

[18] See Footnote no. 17.

[19] See e.g. Culiberg, Šercelj 1991 and Chapter 7 in this monograph.



Sl. 8.18: Kolesna deska A1. Detajl z branikami, ki potekajo pravokotno na letve. Foto: M. Zaplatil.
Fig. 8.18: Wheel plank A1. Detail with annual rings running vertically to battens. Photo: M. Zaplatil.



Sl. 8.19: Kolo s Starih gmajn postavljeno v idealno krožnico. S puščicama je označeno mesto, ki je najbližje strženu drevesa. Risba: T. Korošec. Ni v merilu.
Fig. 8.19: The wheel of Stare gmajne positioned within a perfect perimeter. The area closest to the pith is marked with arrows. Drawn by: T. Korošec. Not in scale.

pri lesu kolesa s povprečno širino 2,7 mm, kar potrjuje zelo skrben in smiseln izbor lesa. Izbrani les je zato imel dokaj visoko gostoto, trdnost ter trdoto in je imel visoko obrabno odpornost, kar je pomembno za življenjsko dobo kolesa. Izbor lesa kaže na to, da so les jesena, ki so ga dobro poznali in množično uporabljali za nosilne kole bivališč, znali optimalno izkoristiti tudi za specialen izdelek, kot je kolo.

Upoštevanje krčenja in nabrekanja lesa je pri izdelku, kot je kolo, prav tako zelo pomembno, saj je bilo izpostavljeno navlaževanju (dež, vožnja po mokrem) in

8. PREHISTORIC WOODEN WHEEL WITH AN AXLE ...

Sl. 8.20: Kolesna deska A1. Pogled na branike v smeri grebenastih letev. Foto: M. Zaplatil.
Fig. 8.20: The wheel plank A1. View on annual rings oriented perpendicularly to the direction of battens. Photo: M. Zaplatil.

why characteristics of individual piece of wood and its orientations are also important at selection. Ash wood with wider annual rings has the best mechanical properties.[20] Moreover, annual rings with an average width of 2.7 mm confirm very careful and rational selection of wood. Wood chosen, had rather high density, strength and hardness and had high impact resistance, which is important for functioning of the wheel. Selection of wood shows that the knowledge of ash wood, which was used massively for foundation piles of the buildings, was also optimally utilized for special products, such as wheels.

Consideration of shrinkage and swelling of wood is very important, because the wheels are exposed to moisture (rain, wet ground) and drying, which is intense when exposed to hot sun. When used in this way, moisture of wood can vary 5–10 %. As shrinkage in radial direction is twice as low as tangentially, wood was rationally oriented (radial plank). Selection of ash wood also makes sense, as it has greater dimensional stability as oak or beech wood, which otherwise have comparable density and mechanical properties to ash. The fact that ash has always been the most popular wood species in wheelwright's trade, used for making wooden wheels, and that it is still the most common wood species used for products requiring high impact strength of wood (e.g. sport equipment and tool handles), prove that wood was chosen rationally.

Battens were made of oak wood. An important advantage of oak in contrary to ash is that oak has coloured heartwood, which is naturally resistant against biological deterioration. The use of heartwood assures better durability of wooden products that are in contact with the ground or are exposed to moisture. Density and strength of oak are analogous to ash. However, ash wood is generally more suitable for dynamic loads. Hygroscopic shrinkage and swelling of oak wood is larger as at ash wood. Production of battens required straight wood as well. Only wood with wide annual rings and with

[20] Čufar 2006.

sušenju, ki je predvsem ob izpostavitvi sončni pripeki zelo intenzivno. Pri uporabi kolesa je zato vlažnost lesa lahko variirala za 5–10 %. Ker je krčenje v radialni smeri dvakrat manjše kot v tangencialni, je bil les smiselno orientiran (radialna deska). Tako je smiselna izbira lesa jesena tudi zato, ker ima večjo dimenzijsko stabilnost kot na primer les hrasta ali bukve, ki imata sicer primerljivo gostoto in trdnost. Da je bil les smiselno izbran, priča tudi to, da je bila jesenovina še tisočletja po tem glavna lesna vrsta v kolarstvu, torej za izdelavo koles, dokler so bila ta še lesena, in je še danes vodilna domača lesna vrsta za izdelke, ki so dinamično obremenjeni (npr. športno orodje in ročaji orodij).

Letve so bile narejene iz hrastovega lesa. Pomembna prednost hrastovega lesa pred jesenovim je ta, da ima hrast obarvano jedrovino, ki je naravno odporna proti biološkim škodljivcem. Uporaba jedrovine zagotavlja daljšo življenjsko dobo lesenim izdelkom, ki so v stiku s tlemi ali so izpostavljeni navlaževanju. Gostota in trdnost hrastovine sta podobni kot pri jesenovini, s tem da slednjo vedno omenjajo kot primernejšo za dinamične obremenitve. Higroskopsko krčenje in nabrekanje lesa hrasta je večje kot pri lesu jesena. Tudi za letve so potrebovali ravno raščen les. Izbrali so les s širšimi branikami brez rastnih anomalij. V izdelku je bil les strogo radialno orientiran, tako da je bilo krčenje grebenastih letev po širini (gledano na kolo) najmanjše (*sl. 8.15–8.17*).

Na osnovi omenjenih lastnosti ne moremo natančno pojasniti, ali so bile letve narejene iz hrastovega lesa zaradi izstopajočih lastnosti hrastovine ali morda samo zato, ker so po naključju imeli na razpolago ustrezen hrastov les.

Iz naštetega je razvidno, da je prazgodovinski kolar odlično poznal lastnosti lesa in da ga je znal optimalno izbrati in uporabiti. Dobro je poznal lesne vrste in tudi variabilnost lastnosti lesa iste vrste ter jih znal s pravilno izbiro, orientacijo in obdelavo izkoristiti. Izdelava kolesa je zahtevala veliko natančnost obdelave. Zato je moral kolar izbrati oz. pripraviti tudi ustrezno orodje in ga spretno uporabiti. Ko gledamo izdelek, lahko potrdimo, da ga je naredil izučen in izkušen mojster. Kolo torej ni eksperimentlani poskus začetnikov, temveč očitno produkt predhodne dolgotrajne tehniške tradicije.

8.3.1.2 PESTO

Središčno odprtino na kolesu imenujemo pesto, ki je pri kolesu s Starih gmajn štirikotne oblike (glej *sl. 8.10, 8.11*). Gre za ključni element, ki najdbo opredeljuje za kolo vozila, posebno še, ker je bil v pesto vstavljen dobro prilegajoči se konec osi a1 (glej *sl. 8.4*, *8.6, 8.21–8.23*). Os se je vrtela skupaj s kolesom, kar kaže, da je bilo vozilo dvokolesno. To predstavlja ugodno konstrukcijsko rešitev za premo gibanje na slabih hribovitih terenih.[21]

[21] Schlichtherle 2002, 31.

no growth anomalies was useful for such purpose. Wood was strictly radially oriented so that shrinkage of batten widths was as low as possible (*Figs. 8.15–8.17*).

We cannot explain, based on the characteristics mentioned, whether battens were made of oak wood because of oak's characteristics, or perhaps only because they happened to have suitable oak wood available at the time.

We can conclude from above that prehistoric wheelwright was aware of characteristics of wood, and he knew how to select and use wood optimally. He was familiar with wood species, as well as with variability of wood properties within the same species; he utilized the advantages of wood with its correct selection, orientation and handling. Producing a wheel demanded precise processing of wood. That is why the wheelwright also had to choose and prepare suitable tools and use them with skill. We can confirm that a skilled wheelwright produced the wheel. A wheel is not an experimental product, but obviously a product of long-term technical tradition and knowledge.

8.3.1.2 HUB

A hub is the central opening on a wheel; it is of a rectangular shape on the wheel from Stare gmajne (see *Figs. 8.10, 8.11*). It is the key element, which verifies that this is a wheel belonging to some sort of a vehicle, particularly because the well fitted end of the axle a1 was fixed into the hub (see *Figs. 8.4, 8.6, 8.21–8.23*). The axle was turning simultaneously with the wheel, which indicates that the cart was two-wheeled. This is an excellent constructional solution for stable and continuous movement over hilly land.[21]

8.3.2 WOODEN AXLE

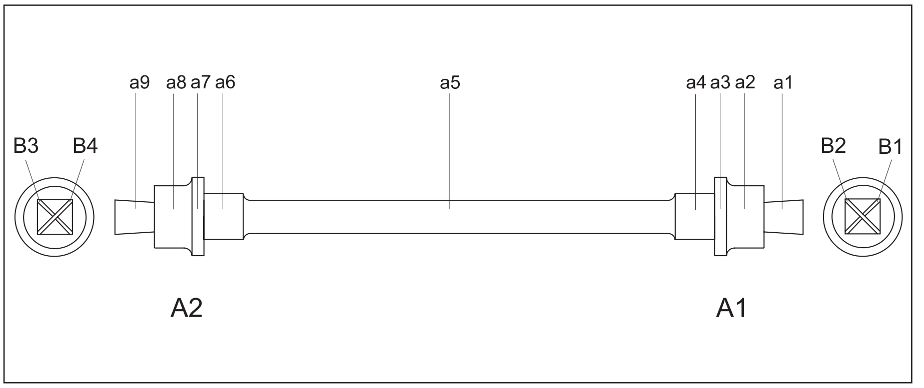
8.3.2.1 AXLE BAR

An axle is a central shaft for a rotating wheel. In this case, the wooden axle is straight and symmetrical, with circular and rectangular (at each end) cross-section (*Figs. 8.22, 8.23*). Both end pieces (A1 and A2) have wedges fixed into the axle (B1–B4).

The axle from Stare gmajne is made of a single piece of oak wood (*Figs. 8.22*, *8.24*). They used a piece of straight stem without knots or other anomalies with a diameter of at least 20 cm.

As mentioned before, strength and hardness of oak and ash wood are similar. Heartwood in the centre of a stem has larger resistance against biological deterioration and the thin sapwood around it is not resistant. It was important that stem was straight and without growth anomalies. It appears, they had a suitable oak trunk available, which is perhaps the main reason for using this wood.

[21] Schlichtherle 2002, 31.



Sl. 8.21: Oznake delov osi. Dimezije osi:
– dl. osi = 125,7 cm
– db. a5 = od 5,4 cm do 6,7 cm; na sredini = 6,1 cm.
Risba: T. Korošec.

Fig. 8.21: Parts of the axle. Dimensions of the axle:
– length = 125.7 cm
– diameter a5 = 5.4 to 6.7 cm; centre = 6.1 cm.
Drawn by: T. Korošec.

8.3.2 LESENA OS

8.3.2.1 DROG

Po definiciji je os drog, ki prenaša vrtenje (na kolo). V našem primeru gre za lesen simetrično izdelan raven drog okroglega in na konceh štirikotnega preseka (*sl. 8.22*, *8.23*). Na obeh straneh (A1 in A2) so v os zabite zagozde (B1–B4).

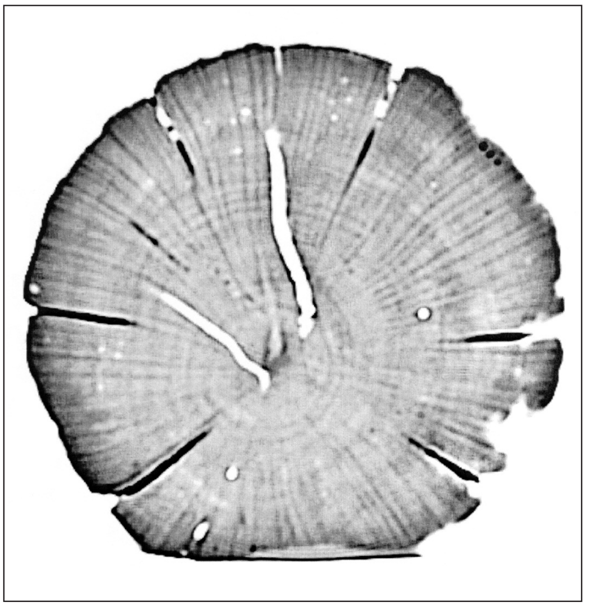
Os s Starih gmajn je izdelana iz enega kosa lesa hrasta (*sl. 8.22*, *8.24*). Očitno so v ta namen uporabili kos ravnega debla brez grč in drugih napak premera vsaj 20 cm.

Kot že omenjeno, je po trdnosti in trdoti les hrasta podoben lesu jesena. Jedrovina na sredini debla ima večjo odpornost proti biološkim škodljivcem, ozka beljava na zunanjem delu pa je neodporna. Pomembno je bilo, da je bilo deblo ravno in brez rastnih napak. Zdi se, da so imeli na razpolago primerno hrastovo deblo, kar je morda glavni razlog za uporabo tega lesa.

Dolžina osi s Starih gmajn je pribl. 125 cm, kar pomeni, da je kolesnica merila pribl. 115 cm. Gre za razpon, ki je v spodnjem območju variacijske širine običajnih kolesnic pri prazgodovinskih vozovih in približno četrt metra krajši od moderne angleške standardne kolesnice, ki znaša 142,6 cm.[22] Kakor koli že, razpon kolesnice je bil verjetno odvisen od velikosti vprežne živali, namembnosti voza, razpoložljivosti poti idr. Krajša os torej ne bi omogočala vprege živali, voz bi se tudi hitreje prevrnil. Veliko daljša os pa bi bila bolj problematična s trdnostnih vidikov. Os je morala imeti tudi ustrezen premer, da je bila zagotovljena potrebna trdnost.

Sl. 8.22 / Fig. 8.22
Sl. 8.23 / Fig. 8.23

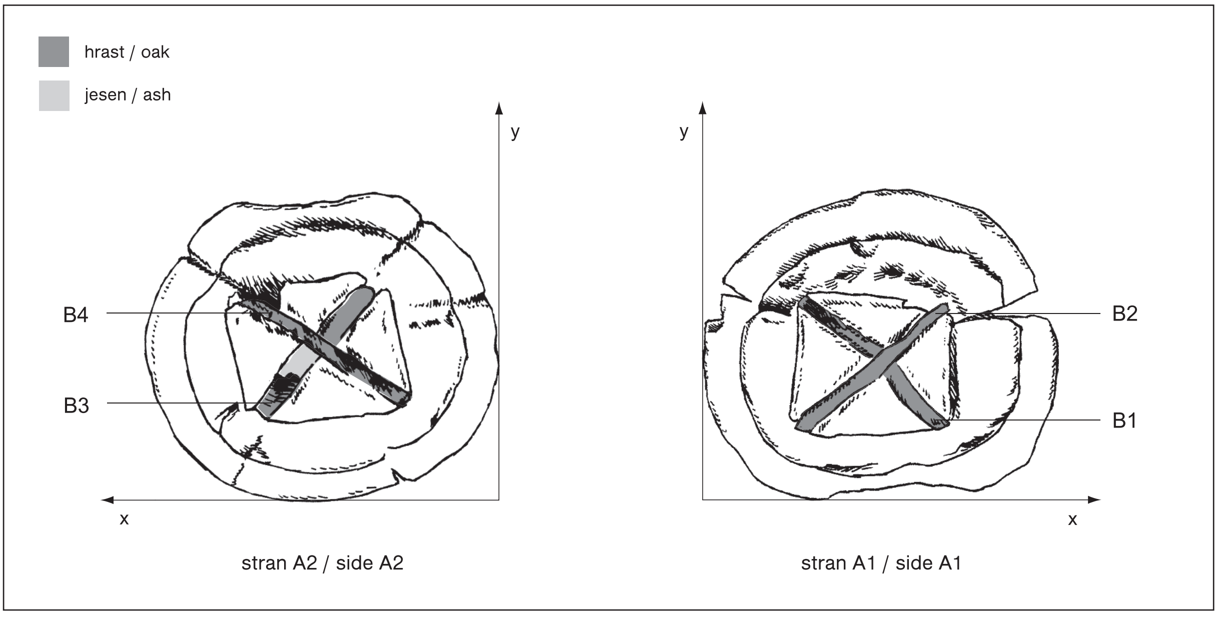
[22] Piggott 1983, 68; Burmeister 2002, sl. 6.



Sl. 8.24: CT prečnega prereza osi. Pripravil: M. Pflaum.
Fig. 8.24: CT of the axle's cross-section. Prepared by: M. Pflaum.

The axle from Stare gmajne is c. 125 cm long, which means, that the rut was c. 115 cm wide. This is a span that is in the lower range of the variation width of the usual ruts of prehistoric carts and c. 0.25 m shorter from a modern English standard rut, that is 142.6 cm.[22] Be that as it may, span of a rut probably depended upon the size of draught animal, intended usage of a cart, available routes etc. Shorter axle would not be suitable for draught animal and cart would be less stable. Moreover, much longer axle would be not as solid. An axle also had to have a suitable diameter, which ensured its necessary strength.

[22] Piggott 1983, 68; Burmeister 2002, Fig. 6.



Sl. 8.25: Konca osi (strani A1 in A2) z zagozdami. Risbi: T. Korošec. M = 1 : 3.
Fig. 8.25: Axle's end pieces (A1 and A2) with wedges. Drawn by: T. Korošec. Scale = 1 : 3.

8.3.2.2 KONCA OSI

Posebno obravnavo zaslužita tudi strani osi A1 in A2, ki sta na konceh a1 in a9 štirikotnega preseka (glej *sl. 8.25*, *8.26* in *8.28*) ter se tako prilegata obliki pesta (prim. s *sl. 8.10* in *8.11*).

Na obeh koncih a1 in a9 najdemo po dve zagozdi[23] (*sl. 8.25, 8.26*). Identifikacija lesa zagozd (*sl. 8.27*) je pokazala, da so narejene iz hrastovine. V primeru zagozde

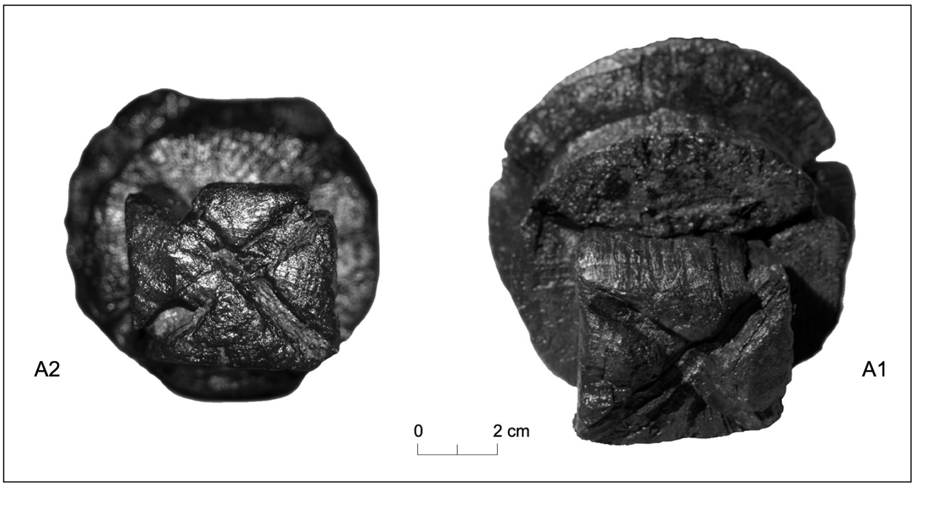
[23] Slovenski jezik pozna več izrazov za predmet, ki preprečuje, da kolo ne pade, zdrsne z osi, med katerimi naj omenimo še dva: osnik (Slovar slovenskega knjižnega jezika 3, Ljubljana 1979, 455) in lunek (Slovar slovenskega knjižnega jezika 2, Ljubljana 1975, 653).

8.3.2.2 AXLE'S END PIECES

Axle's end pieces A1 and A2, with rectangular cross-section ends a1 and a9 (see *Figs. 8.25*, *8.26* and *8.28*), which fit into the hub (compare with *Figs. 8.10* and *8.11*), need to be mentioned.

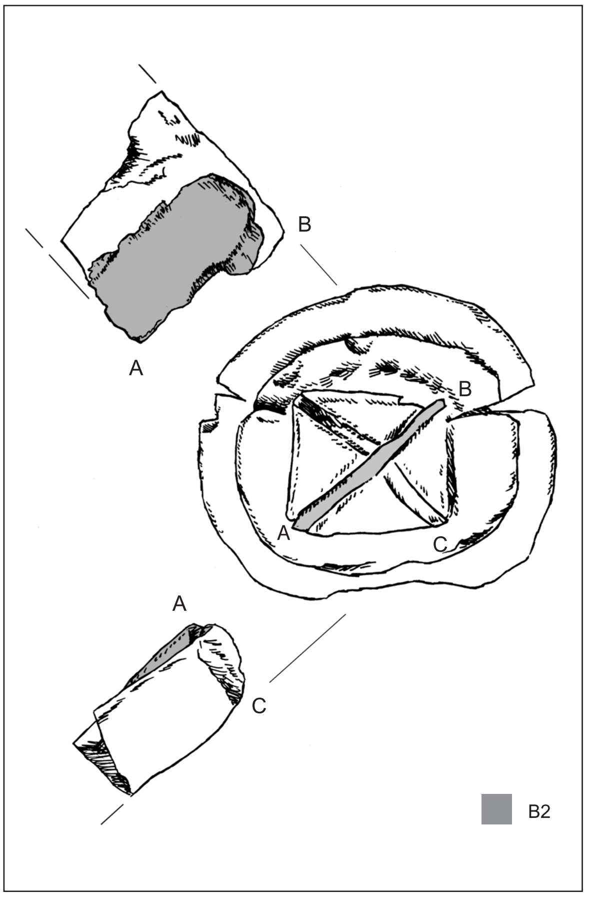
Ends a1 and a9 contain two wedges each (*Figs. 8.25, 8.26*). Wedges were made of oak (*Fig. 8.27*). Moreover, the wedge B3 had a smaller ash wood wedge added later (*Fig. 8.25:* left). The wheel was perhaps falling off the axle, and it needed to be attached firmer. This is also what wedges are used for.

As the wheel detached itself from the axle, which broke off on the side A1 (*Figs. 8.4* and *8.28*), we can



Sl. 8.26: Os. Stran A2 in stran A1. Foto: M. Turk.
Fig. 8.26: Axle. End pieces A2 and A1. Photo: M. Turk.

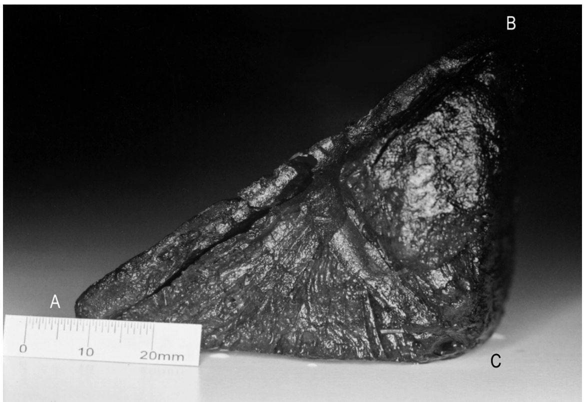
Sl. 8.27: M. Zupančič pri pripravi vzorca za identifikacijo lesa zagozd. Foto: M. Turk.
Fig. 8.27: M. Zupančič at preparation of a sample for identification of wood of wedges. Photo: M. Turk.



Sl. 8.29: Zagozda B2. Risba: T. Korošec. M = 1 : 3.
Fig. 8.29: Wedge B2. Drawn by: T. Korošec. Scale = 1 : 3.

Sl. 8.28: Os. Stran A1 z zagozdo B2. Foto: M. Turk.
Fig. 8.28: Axle. The end piece A1 with the wedge B2. Photo: M. Turk.

Sl. 8.30: Zagozda B2 v ležišču. Foto: M. Zaplatil.
Fig. 8.30: Wedge B2 in bed. Photo: M. Zaplatil.



Sl. 8.31: Zagozda B2. Pogled v smeri osi. Foto: M. Pflaum.
Fig. 8.31: Wedge B2. View in direction of axle. Photo: M. Pflaum.

B3 pa je bila naknadno dodana manjša zagozda iz jesenovega lesa (*sl. 8.25:* levo). Verjetno se je kolo snemalo in ga je bilo treba pričvrstiti, kar je tudi funkcija zagozd.

Po zaslugi dejstva, da se je ob odkritju kolo snelo z osi in se je pri tem os na strani A1 odlomila (*sl. 8.4* in *8.28*), lahko rekonstruiramo tudi potek zabijanja zagozd v os. Na koncu osi a1 smo namreč naleteli na v celoti ohranjeno zagozdo B2 (*sl. 8.28–8.31*).

Zagozde so zabili po tem, ko je kolo že bilo nataknjeno na os (*sl. 8.32*). Pred tem so verjetno le pripravili ležišče (*sl. 8.32a:* 1).

Skratka, verjetno predhodno zasekana os je bila vstavljena v pesto. V primeru strani A1 je sledilo zabijanje zagozde B1 in šele nato zagozde B2; v primeru strani A2 pa je prišla najprej na vrsto zagozda B3 in nato B4 (*sl. 8.25*).

Dobro pritrjene zagozde so preprečevale ohlapno pritrditev kolesa oz. njegovo snemanje. Ker les deluje, se krči in nabreka, je bilo vozilo zanesljivo treba vzdrževati in popravljati, kar kaže tudi že omenjena manjša zagozda ob zagozdi B3, ki je bila verjetno vložena naknadno (*sl. 8.25:* levo). Tudi grebenaste letve v utorih so verjetno pričvrstili z dodatnim zabijanjem, kadar je vez zaradi sušenja lesa postala ohlapna.

reconstruct the course of fitting of wedges into the axle. We came across an entirely preserved wedge B2 on the side a1 (*Figs. 8.28–8.31*).

Wedges were fitted after the wheel was already fixed onto the axle (*Fig. 8.32*). Some preparation was most likely done before this (*Fig. 8.32a:* 1).

Probably preliminarily incised axle was fitted into the hub. Wedge B1 was rammed first into the end piece A1 and wedge B2 second; wedge B3 and then B4 were rammed into the end piece A2 (*Fig. 8.25*).

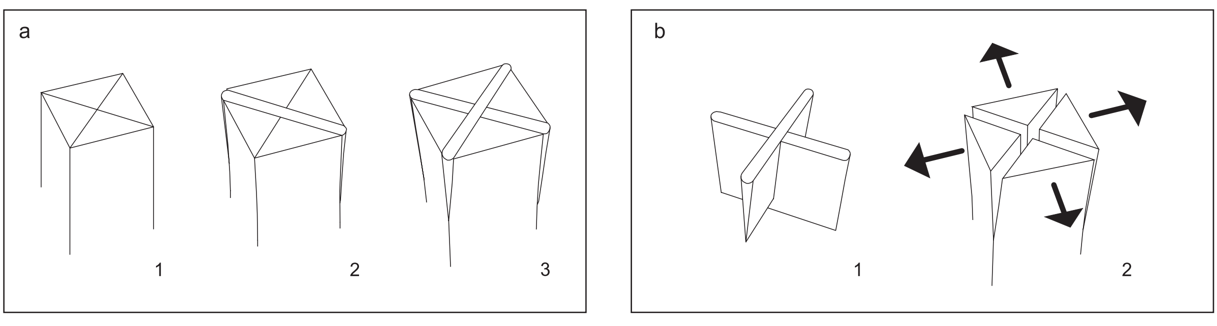
Well-fitted wedges made loosening of the wheel or falling off impossible. Wood shrinks and swells all the time, so the cart had to be maintained and repaired. Already mentioned smaller wedge next to the wedge B3, which was probably fitted later (*Fig. 8.25:* left), proves this. Battens were probably fitted to grooves also with additional fitting after the connection became loose because of drying of wood.

8.4 PRESERVATION OF THE WHEEL AND THE AXLE AND THEIR DAMAGE

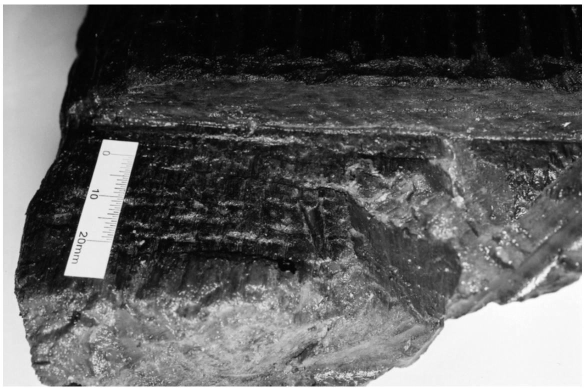
8.4.1 WHEEL DAMAGE

Several wheel damages were noticed. We classified them according to their origin.

a) Planned or unplanned changes on the surface, which occurred during the process of making of the wheel: the outer surface of the wheel is relatively smooth, while the inner surface (e.g. plank A1) shows visible traces of rougher chiselling (*Figs. 8.10, 8.11*). Manufacturing traces are also visible on battens (*Figs. 8.10* and *8.39b*). However, some of the individual cuts were unplanned, such as cut on the edge of the batten B3 on the wheel plank A1, for example (*Fig. 8.11b*). Damages, done during the processing, are seen as parallel cuts, visible in bed of the batten B3 (*Fig. 8.33*), as cuts on the batten B3 in the hub (*Fig. 8.34*) and as a gully with gouges in the corner of the hub on the wheel plank A1 (*Fig. 8.35*).



Sl. 8.32a in *b:* Prikaz postopka zagozdenja na podlagi najdbe s Starih gmajn. Risbe: T. Korošec.
Fig. 8.32a and *b:* Wedging procedure, based on the find from Stare gmajne. Drawn by: T. Korošec.



Sl. 8.33: Vzporedne zareze v ležišču letve B3 na kolesni deski A2. Foto: M. Pflaum.
Fig. 8.33: Parallel cuts in bed of the batten B3 on the wheel plank A2. Photo: M. Pflaum.

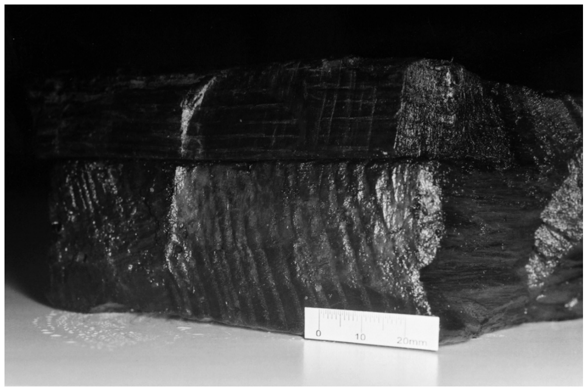
8.4 OHRANJENOST KOLESA IN OSI TER POŠKODBE

8.4.1 POŠKODBE NA KOLESU

Na kolesu smo opazili več poškodb, ki smo jih po izvoru razdelili v različne kategorije.

a) Načrtne ali nenačrtne spremembe na površju, nastale pri izdelavi kolesa: zunanja stran kolesa je bila dokaj gladko in ravno obdelana, na notranji strani (npr. deska A1) pa so vidni sledovi bolj grobe obdelave z dletom ali podobnim orodjem (*sl. 8.10, 8.11*). Sledove izdelave lahko opazimo tudi na samih letvah (*sl. 8.10* in *8.39b*), s tem da so posamezne zareze nastale tudi nenačrtno kot npr. na koncu letve B3 na kolesni deski A1 (*sl. 8.11b*). Med poškodbe nastale pri izdelavi, uvrščamo tudi vzporedne zareze, ki so vidne v ležišču letve B3 (*sl. 8.33*), zareze na letvi B3 v pestu (*sl. 8.34*) in žleb z vdolbinami v vogalu pesta na kolesni deski A1 (*sl. 8.35*).

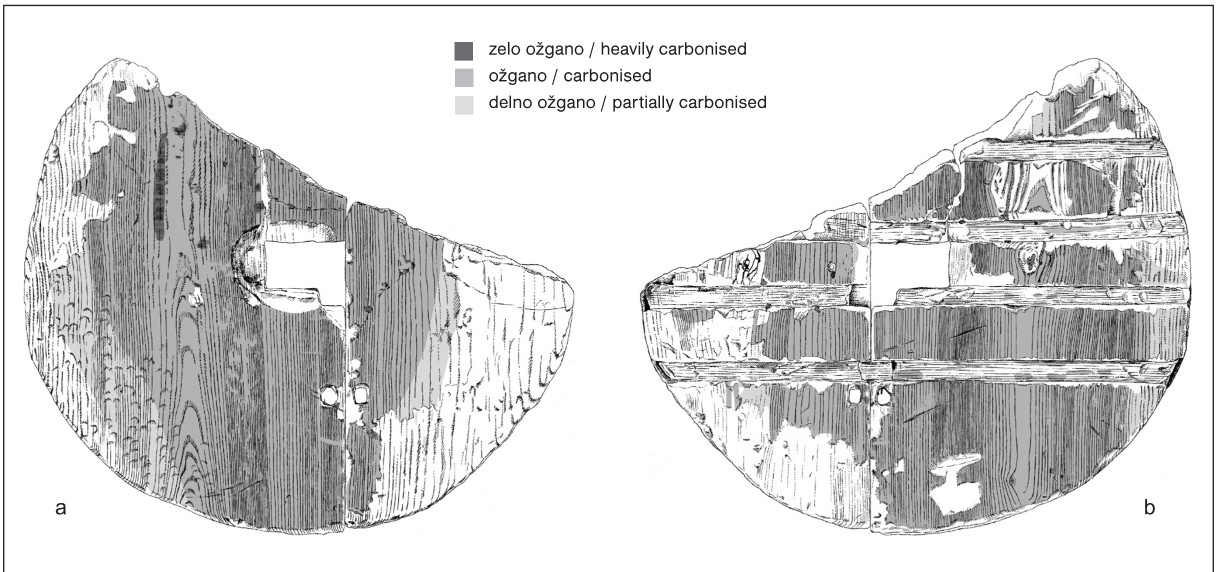
Na podlagi analogij iz jugozahodne Nemčije[24] smo bili pri preučevanju kolesa pozorni tudi na sledove morebitnega ožiganja na obeh kolesnih deskah in tudi na hrbtišču grebenastih letev (*sl. 8.36*). Pri pregledu kolesa se nam je zdelo, da bi bila površina lahko ožgana (*sl. 8.37a*). Domnevo je potrdil pregled lesa pod mikroskopom (*sl. 8.37b*), kjer lahko vidimo temno plast lesa (oglja) na ožgani površini. Tega pa nam ni uspelo preveriti s kemijskimi analizami, pri katerih bi upoštevali, da je v normalnem lesu okoli 50 % ogljika, v kemijsko močno spremenjenem oglju pa je ta delež po pričakovanju bistveno višji. Ker je morebitna plast ogljika na površini zelo tanka, bi zato morali uporabiti metodo, pri kateri zadostuje za analizo že zelo majhna količina materiala.



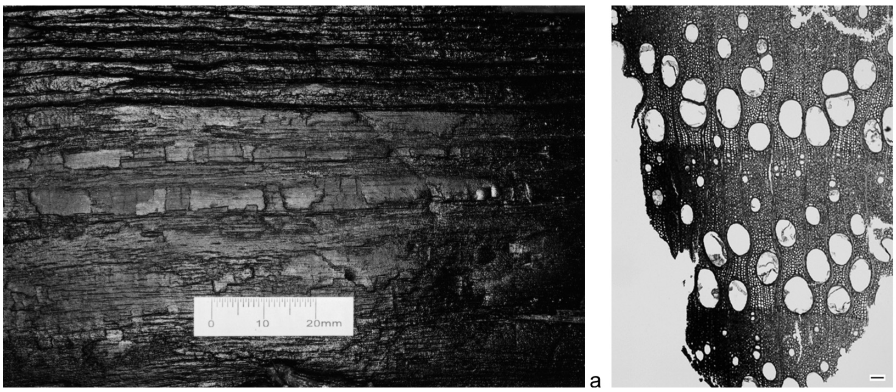
Sl. 8.34: Pogled na pesto in grebenasto letev B3 na odlomljenem delu kolesne deske A1 (glej *sl. 8.10* in *8.11*). Razvidno je, da je bila letev vložena pred izdelavo pesta. Vidne so tudi krajše zareze, nastale s tesanjem oz. dolbenjem. Foto: M. Pflaum.
Fig. 8.34: View on the hub and the batten B3 on the broken part of the wheel plank A1 (see *Figs. 8.10* and *8.11*). It is visible that the batten was fitted before creating the hub. Short cuts, made by hewing or chiselling, are also visible. Photo: M. Pflaum.

Sl. 8.35: Pogled na vogal v pestu z letvijo B3 (desno spodaj) na kolesni deski A1. Foto: M. Pflaum.
Fig. 8.35: View on the corner in the hub with the batten B3 (bottom right) on the wheel plank A1. Photo: M. Pflaum.

[24] Schlichtherle 2002, 20–23.



Sl. 8.36: Kolo. Svetlejša in temnejša, ožgana, območja na notranji (a) in zunanji (b) strani kolesa. Risbi: T. Korošec.
Fig. 8.36: The wheel. Brighter and darker, scorched, areas on the inner (a) and outer (b) surface of the wheel. Drawn by: T. Korošec.



Sl. 8.37: Sledovi ožiganja – (a) površina lesa na notranji strani kolesne deske A1 (foto: M. Pflaum) in (b) mikroskopski pogled lesa, odvzetega s površine deske (foto: M. Zupančič); temnejši približno 0,5 mm debel sloj predstavlja pooglenelo lesno tkivo. Merilna daljica 100 µm.
Fig. 8.37: Traces of scorching – (a) wood on the inner surface of the wheel plank A1 (photo: M. Pflaum) and (b) microscopic view of wood taken from the surface of the plank (photo: M. Zupančič); darker, c. 0.5 mm thick layer is charred wood tissue. Scale bar: 100 µm.

Po navedbah[25] so v preteklosti les ožigali, da bi povečali njegovo trdoto in ga zaščitili pred nekaterimi škodljivci. Poudariti pa je tudi treba, da se barva lesa jesena zaradi kemijskih sprememb v tisočletjih zelo spremeni (potemni), zato je dokazovanje ožiganja še toliko težavnejše.

b) Poškodbe zaradi uporabe so predvidljive in so posledica obrabe na najbolj obremenjenih mestih, kjer prihaja do trenja, npr. obraba oboda kolesa in mesta, kjer se je vrteča se os drgnila ob druge dele vozila.

[25] Schlichtherle 2002, 20.

Based on analogies from southwestern Germany,[23] we were also looking for traces of eventual scorching on both wheel planks and on the back of the battens (*Fig. 8.36*). It seems that the surface could be scorched (*Fig. 8.37a*). Examination of wood under a microscope confirmed this assumption (*Fig. 8.37b*); we could see a dark layer of wood (charcoal) on a scorched surface. We did not manage to check this with chemical analyses, where we would consider that there is c. 50 % of carbon present in normal wood and much more in chemically changed charcoal. As the suspected layer of carbon on the surface

[23] Schlichtherle 2002, 20–23.

Sl. 8.38: Pesto na notranji strani kolesne deske A1 z obrabljenim delom, kjer je bilo kolo v stiku z osjo. Foto: M. Pflaum.
Fig. 8.38: Hub on the inner side of the wheel plank A1 with worn part, where the wheel was rubbing against the axle. Photo: M. Pflaum.

Na *sliki 8.19* je vidno, da kolo ni povsem okrogle oblike, tam, kjer so branike širše, je jesenov les trši. Obraba je večja na mestih, kjer vlakna potekajo vzporedno z obodom kolesa, in manjša tam, kjer vlakna potekajo pravokotno na obod. Poškodba je najverjetneje nastala tudi ob drgnjenju z osjo in je vidna tudi na notranji strani kolesa okoli pesta (*sl. 8.38*).

Drugih posebej vidnih poškodb, ki naj bi nastale zaradi uporabe na kolesu, nismo zaznali, pri čemer naj še enkrat poudarimo, da je les jesena dokaj trd. Trd je predvsem kasni les, ki prevladuje v lesu kolesa z relativno širokimi branikami.

c) Poškodbe, ki so nastale zaradi t. i. postdepozicijskih procesov, so bolj nepredvidljive in jih težje razložimo. Na osnovi stratigrafije in ohranjenosti, ki je možna

is very thin, we would have to use a procedure where a small amount of material is enough for analyses.

People were scorching wood in the past to harden it and to protect it against some pests.[24] It has to be emphasized that the colour of ash wood darkens over millennia due to chemical changes. That is why scorching is even harder to prove.

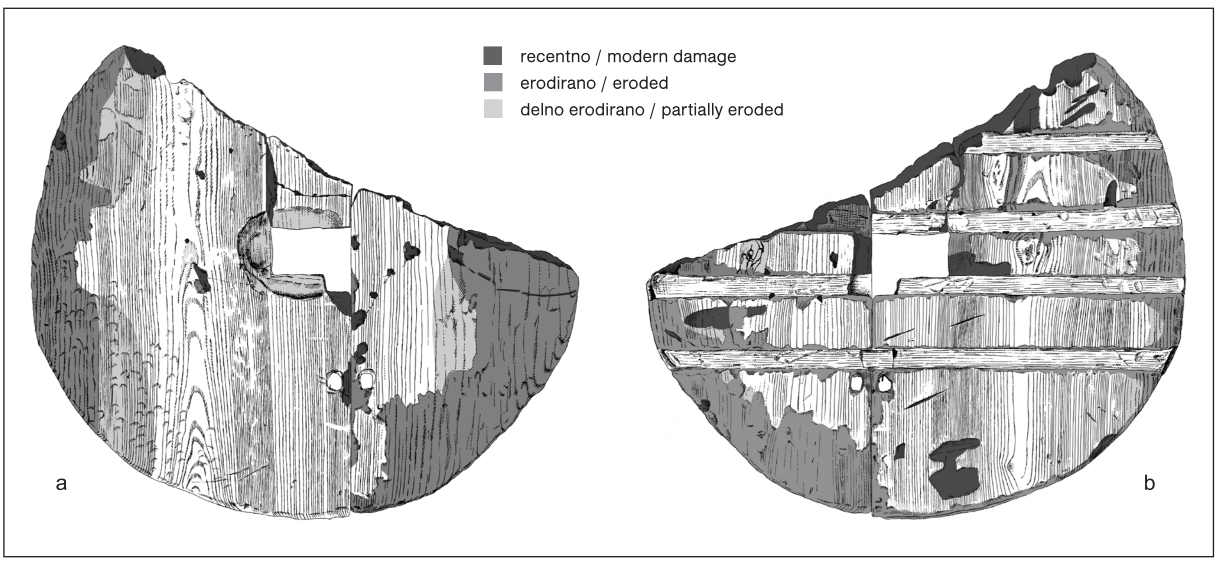
b) Use-wear damages are predictable and are a consequence of wear of the parts that are most burdened by friction, e.g. wear on the rim of the wheel and areas where the turning axle rubbed against other parts of the vehicle.

As seen on *Fig. 8.19,* the wheel is not completely circular; ash wood is harder on places where annual rings are wider. Wear out is faster where fibres run parallel with the rim of the wheel and slower where fibres run vertically to the rim. Damage most probably occurred at rubbing with the axle and is also visible around the hub on the inner surface of the wheel (*Fig. 8.38*).

There were no other visible damages that would occur at the use of the wheel. It has to be emphasized once more, that ash wood is relatively hard. Particularly hard is late wood which is predominating in the wood of which the wheel has been made.

c) Damage that occurred at so-called post-deposit processes is unpredictable and harder to explain. Based on stratigraphy and preservation, which occurs only underwater, where there is not enough oxygen for activity of destructive organisms, we could presume that the wheel was probably waterlogged after use.[25] Traces of

[24] Schilchtherle 2002, 20.
[25] Compare with Chapters 2 and 3 in this monograph.



Sl. 8.39: Kolo. Poškodbe na površju notranje strani kolesa (a) in poškodbe na površju zunanje strani (b). Risbi: T. Korošec.
Fig. 8.39: Wheel. Damages on the inner (a) and the outer (b) surfaces of the wheel. Drawn by: T. Korošec.

Sl. 8.40: Zunanja stran kolesne deske A2, kjer je na obodu kolesa vidna obrabljena površina. Foto: M. Zaplatil.
Fig. 8.40: Outer surface of the wheel plank A2; a worn surface is visible on the rim of the wheel. Photo: M. Zaplatil.

samo pod vodo, kjer ni kisika za delovanje destruktivnih organizmov, bi lahko sklepali, da je po končani uporabi kolo verjetno nekaj časa ležalo v vodi.[26] Sledovi obrabe so tako v veliki meri posledica ležanja v vodi in so vidni predvsem na zunanji strani kolesne deske A2 (*sl. 8.40*). Posledica tako nastalih procesov so verjetno tudi močno obrabljeni robovi utorov za letve (*sl. 8.10b, 8.39b* in *8.40*). Ne smemo pa prezreti, da je do obrabe zaradi postdepozicijskih procesov prišlo šele po stoletjih oz. tisočletjih ležanja v vodi ali mokrih tleh, ko je bila kemijska zgradba lesa že zelo spremenjena.

č) Četrta kategorija poškodb so t. i. recentne poškodbe, ki so nastale zaradi recentnega rastlinja, predvsem pa neposredno ob odkritju kolesa in po njem, ko smo ga prenesli z arheološkega najdišča (glej *sl. 8.39*).

Približno tretjino kolesa je odrezal stroj za kopanje jarkov neposredno pred odkritjem kolesa. Pozneje, ko smo kolo odkrili in ga skušali odlepiti od blatne podlage, se je še dodatno prelomilo na več delov. Ob tem se je najbolj poškodovala kolesna deska A1, katere del pri pestu se je odlomil in izgubil. Manj pomembne, toda opazne so tudi poškodbe, nastale zaradi uporabe orodja pri arheološkem izkopavanju, in na koncu manjša poškodba, dolga dober cm, ki smo jo povzročili na obodu kolesa

[26] Prim. s poglavjema 2 in 3 v tem zborniku.

wear are, in large degree, consequences of this and are visible mainly on the outer surface of the wheel plank A2 (*Fig. 8.40*). Strongly worn edges of grooves for battens are probably a result of the same processes (*Figs. 8.10b, 8.39b* and *8.40*). However, we should not forget that the wear at post-deposit processes occurred after centuries or millennia in water or wet floor, when chemical structure of wood was already drastically changed.

d) The fourth category of damages are so-called recent damages that occurred because of recent vegetation and, mainly, directly at the discovery of the wheel and while removing it from the archaeological site (see *Fig. 8.39*).

Directly before the discovery of the wheel, JCB cut off approximate one third of it. Later, when we tried to detach the wheel from a muddy base, it got damaged even more. Wheel plank A1 was the most damaged one, with part at the hub broken off and lost. Less important, but still noticeable, are also damages, which occurred at archaeological excavation and, finally, a short, only a few cm long scratch, that had to be done on the rim of the wheel in order to measure annual ring widths – on the rim of the wheel plank A1, where annual rings are visible in a cross-section (*Fig. 8.39b*). We took c. 1 cm^3 of wood from the wheel and the axle for the purposes of the radiocarbon analysis (*Fig. 8.47*).

8.4.2 AXLE DAMAGE

Similarly as on the wheel, we can notice several damages on the axle. We classified them according to their origin.

a) Planned or unplanned changes/damages on surface that were done while making the axle: as expected, there are only a few damages on the axle. Longer cuts on end pieces a1 and a9 are most visible. We can also see short cuts (*Fig. 8.41*) and gullies between individual differently thick parts (e.g. *Fig. 8.42*); all damage was done at the handling of wood for the axle.

We do not know whether the axle was scorched similarly as assumed for the wheel. Axle is made of oak and its heartwood blackened after being deposited in wet ground for millennia, which makes visual judgement difficult.

b) There are some more recent damages: they mostly occurred at the discovery and lifting of the find and later research. As on the wheel, plants penetrated also through the axle (*Fig. 8.43*).

zaradi merjenja širin branik – na obodu kolesne deske A1, samo na mestu, kjer so branike vidne v prečnem prerezu (*sl. 8.39b*). Za radiokarbonsko analizo smo iz kolesa in osi odvzeli po 1 cm^3 lesa (*sl. 8.47*).

8.4.2 POŠKODBE NA OSI

Podobno kot na kolesu smo tudi na osi opazili več poškodb, ki smo jih po izvoru razdelili v različne kategorije.

a) Načrtne ali nenačrtne spremembe oz. poškodbe na površju, nastale pri izdelavi osi: tovrstnih poškodb je na osi razmeroma malo, kar je pričakovano. Najvidnejše so daljše vreznine na konceh osi a1 in a9, opazni pa so tudi kratke zareze (*sl. 8.41*) in žlebovi med posameznimi različno debelimi deli (npr. *sl. 8.42*); vse je nastalo med obdelavo lesa za os.

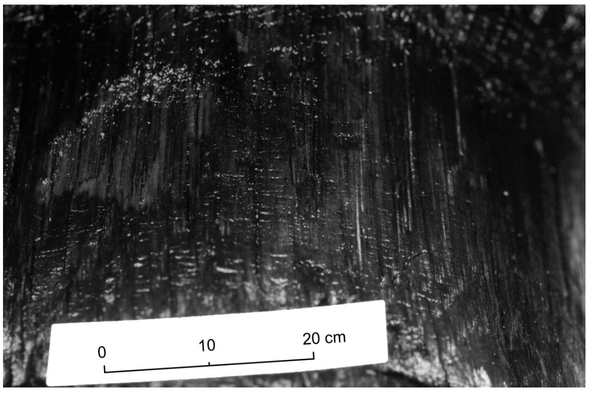
Postavlja se vprašanje, ali je bila ožgana tudi os, podobno kot domnevamo, da je bilo ožgano kolo. Os je namreč narejena iz hrastovega lesa, katerega jedrovina je po tisočletjih v mokrih tleh počrnela, kar oteži vizualno presojo.

8.4.3 MICROSCOPIC AND CHEMICAL CHANGES ON WOOD

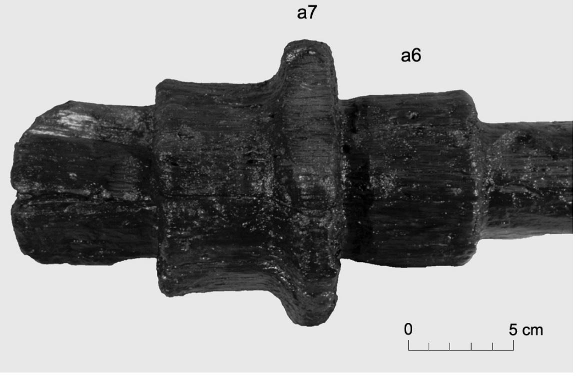
Wood is basically a non-durable material and it repeatedly surprises us that it can last for several thousand years under certain circumstances. However, what kinds of changes appear on it after being underwater or in wet soil for millennia? Rather accurate data on changes of physical (e.g. density) and chemical properties of archaeological ash and oak wood from the Ljubljansko barje of comparable age to the wheel exist. 5000 years old archaeological ash wood has c. 6 times lower density as recent wood. Archaeological wood contains predominantly lignin (c. 70 %), while the proportions of cellulose and hemicelluloses are only c. 8 %. In contrary, recent ash wood contains c. 25 % lignin, 40 % cellulose and 35 % hemicelluloses.[26]

Changes of microscopic structure of archaeological wood are well investigated.[27] Under a microscope, we can see that the majority of wood-anatomical features are kept in archaeological wood (*Figs. 8.44a, 8.44c*). Cell

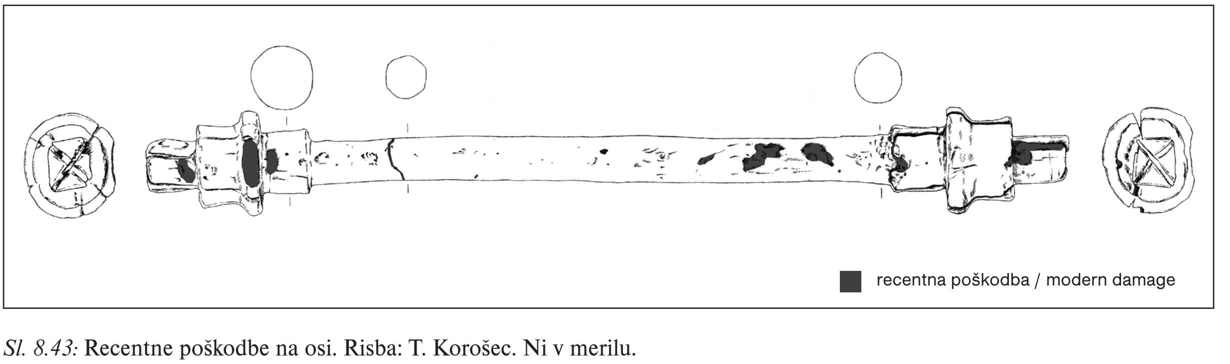
[26] Čufar, Gorišek, Tišler 2002.
[27] Čufar et al. 2008.



Sl. 8.41: Kratke zareze na odseku a4, nastale pri izdelavi osi. Foto: M. Pflaum.
Fig. 8.41: Short cuts in section a4, made during making of the wheel. Photo: M. Pflaum.



Sl. 8.42: Os. Stran A2 z žlebom med odsekoma a6 in a7. Foto: M. Zaplatil.
Fig. 8.42: Axle. Side A2 with a gully between sections a6 and a7. Photo: M. Zaplatil.



Sl. 8.43: Recentne poškodbe na osi. Risba: T. Korošec. Ni v merilu.
Fig. 8.43: Recent damages on the axle. Drawn by: T. Korošec. Not in scale.

b) Nekoliko več je recentnih poškodb: slednje so večinoma nastale pri odkrivanju oz. dvigovanju najdbe in poznejšem preučevanju. Tako kot na kolesu je bilo opaziti, da so si na nekaj mestih skozi os utrle pot rastline (*sl. 8.43*).

8.4.3 MIKROSKOPSKE IN KEMIJSKE SPREMEMBE NA LESU

Ker je les v bistvu netrajen material, nas vedno znova preseneča, da se v nekaterih okoliščinah lahko ohrani tudi več tisoč let. Ob tem se hkrati sprašujemo, kakšne spremembe je utrpel po tisočletjih pod vodo ali v mokrih tleh. Za arheološki les jesena in hrasta z Ljubljanskega barja primerljive starosti, kot je kolo, imamo na razpolago dokaj natančne podatke o spremembah fizikalnih (npr. gostote) in kemijskih lastnosti. 5000 let star arheološki les jesena ima približno 6-krat manjšo gostoto kot normalen les. V njem prevladuje lignin (pribl. 70 %), celuloze in hemiceluloz pa je le okoli 8 %, medtem

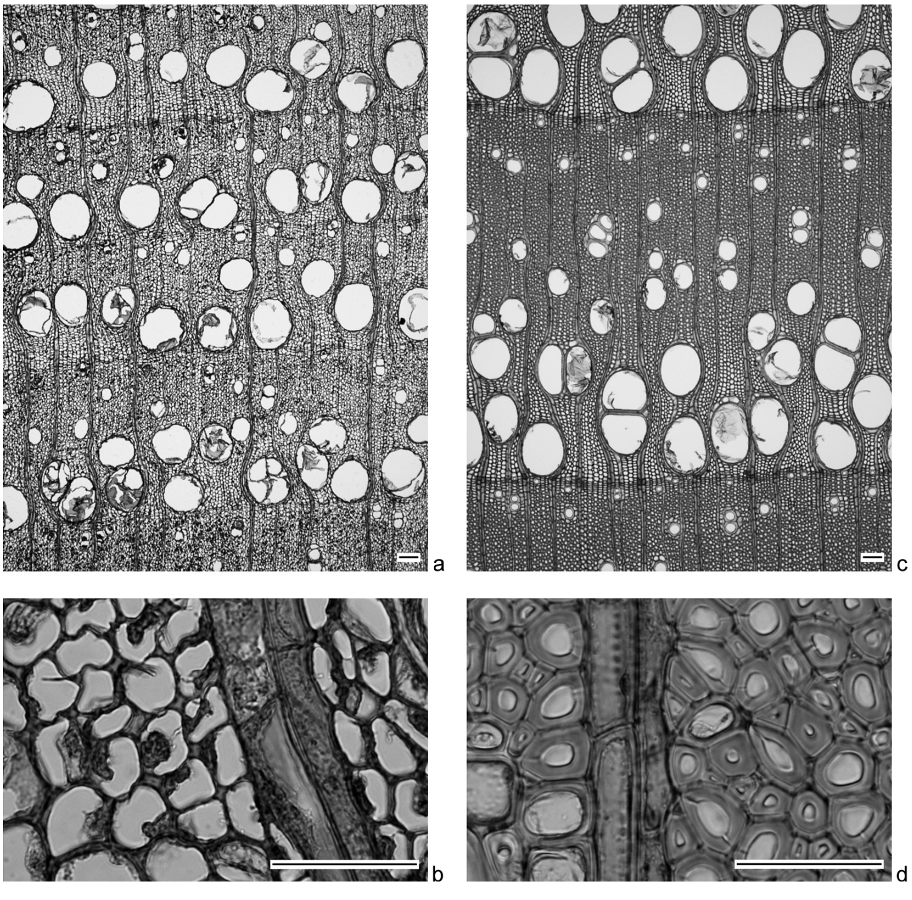
walls are much thinner in archaeological as in recent wood (*Figs. 8.44b, 8.44d*), which explains shrinkage of wood and reduction of its density. Decay of ash wood is generally greater as decay of oak heartwood.[28]

Although it was assumed for a long time that changes on archaeological wood are mostly a consequence of abiotic factors, recent findings show that changes are most probably caused by bacteria.[29] As long as archaeological wood is stored where preserved (underwater or in wet ground), bacteria decompose it very slowly, but they can completely deteriorate it in a few years after the excavation.[30] These findings are very important for suitable conservation and storage of the wheel and its axle.

[28] Čufar et al. 2008.

[29] Björdal, Nilsson, Daniel 1999; Klaassen 2008; Nilsson, Björdal 2008.

[30] Kim, Singh 2000.



Sl. 8.44: Mikroskopska slika zgradbe lesa arheološkega jesena, starega približno 5200 let (a, b), in normalnega lesa jesena (c, d). Pri arheološkem lesu so celične stene zelo tanke, lumni pa vsebujejo ostanke razkrojene celične stene (b). Pri normalnem lesu jesena je celična stena bistveno debelejša. Foto: M. Zupančič. Merilne daljice: 100 µm (a, c), 50 µm (b, d).

Fig. 8.44: Microphotograph of wood structure of c. 5200 years old archaeological ash wood (a, b) and of recent ash wood (c, d). Archaeological wood contains very thin cell walls and lumina contain remains of a decomposed cell wall (b). Cell walls are much thicker at recent ash wood. Photo: M. Zupančič. Scale bar: 100 µm (a, c), 50 µm (b, d).

ko normalen les jesena vsebuje približno 25 % lignina, 40 % celuloze in 35 % hemiceluloz.[27]

Dobro so raziskane tudi spremembe mikroskopske zgradbe arheološkega lesa.[28] Pod mikroskopom lahko vidimo, da je v njem ohranjena večina lesnoanatomskih znakov (*sl. 8.44a, 8.44c*), celične stene pa so bistveno tanjše kot pri lesu (*sl. 8.44b, 8.44d*), kar pojasnjuje veliko izgubo lesne mase in zmanjšanje gostote. Razkroj jesenovega lesa je v splošnem večji kot razkroj hrastove jedrovine.[29]

Čeprav je dolgo veljalo, da so spremembe na arheološkem lesu predvsem posledica abiotskih dejavnikov, v zadnjem času vse bolj ugotavljajo, da jih najverjetneje povzročajo bakterije.[30] Dokler arheološki les ostaja tam, kjer se je ohranil (pod vodo ali v mokrih tleh), ga bakterije razkrajajo zelo počasi, po izkopu pa ga lahko že v nekaj letih popolnoma razkrojijo.[31] To vse je zelo pomembno za ustrezno konzerviranje in hrambo kolesa ter osi.

8.5 DATIRANJE

Kolo z osjo smo datirali posredno in neposredno. Posredna datacija temelji na stratigrafski legi kolesa z osjo in na relativnih ter absolutnih datacijah naselbine. Os, na katero je bilo pritrjeno kolo, je ležala tik pod kulturno plastjo (*sl. 8.5*), kar kaže, da bi bila najdba lahko del ostankov s koliščarske naselbine. Slednje potrjujejo tudi spremljajoče arheološke najdbe, kot sta fragmenta dveh značilnih posod, ki sta bila najdena v bližini osi,[32] še posebej fragment lonca, ki je ležal poleg konca osi na strani A2 (*sl. 8.45*).

Tipološka analiza keramike je pokazala, da sodi koliščarska naselbina v horizont koliščarskih naselbin druge polovice 4. tisočletja pr. Kr.[33] Še največ analogij smo našli na bližnji Blatni Brezovici, v Notranjih Goricah in na Maharskem prekopu, na podlagi česar smo sklepali, da naselbine sodijo v isti kulturni horizont.[34] Slednje potrjujejo tudi dendrokronološke raziskave in radiokarbonsko datiranje.[35]

Natančnejše datiranje na splošno omogočata dendrokronološka in radiometrična metoda.

S pomočjo dendrokronološke metode[36] smo iz lesa, dokumentiranega med letoma 2002 in 2007, sestavili več kronologij širin branik, s pomočjo katerih smo postavili

[27] Čufar, Gorišek, Tišler 2002.

[28] Čufar et al. 2008.

[29] Čufar et al. 2008.

[30] Björdal, Nilsson, Daniel 1999; Klaassen 2008; Nilsson, Björdal 2008.

[31] Kim, Singh 2000.

[32] Glej poglavje 3 v tem zborniku: *t. 3.1*: 1,2.

[33] Glej poglavje 1 v tem zborniku.

[34] Glej poglavje 1.3 v tem zborniku.

[35] Glej poglavje 7 v tem zborniku.

[36] Glej poglavje 7 v tem zborniku.

8.5 DATING

We indirectly and directly dated the wheel with its axle. Indirect dating is based upon the wheel's and axle's stratigraphic position, relative and absolute dating of the settlement. The axle, on which the wheel was fixed, was deposited just under a cultural layer (*Fig. 8.5*). This indicates that the find and the pile-dwelling settlement could be contemporary. The latter can also be confirmed by accompanying archaeological finds, a couple of characteristic pottery fragments found in the vicinity of the axle,[31] and especially fragment of a pot, found beside the axle's end piece A2 (*Fig. 8.45*).

Typological analysis of pottery dated the pile-dwelling settlement to the horizon of pile-dwelling settlements of the second half of the 4th millennium BC.[32] Most analogies can be found at the nearby sites of Blatna Brezovica, Notranje Gorice and Maharski prekop. Consequently, we assumed that settlements form one cultural horizon.[33] Dendrochronological research and radiocarbon dating additionally confirmed this assumption.[34]

Dendrochronological and radiometric procedures enable even more detailed dating.

Several annual ring chronologies were produced with the help of dendrochronological procedure[35] and wood documented between 2002 and 2007. They helped us to place activities on the pile-dwelling settlement to a relative time frame. As chronologies were absolutely dated with the radiometric procedure, we combined the results of both procedures to date the finishing phase of the settlement to c. 3109 ± 12 cal BC, and found out that it was intensely settled since over 50 years earlier.

Both procedures, dendrochronological and radiometric, are suitable for dating of the wheel and the axle. However, they both have restraints, particularly as we wanted to date only two pieces of wood of different wood species. The axle contained only 44 annual rings, which is not enough for reliable dendrochronological dating. Therefore, we focused our attention mainly to the analysis of tree-ring widths of the wheel (plank A1), where we measured 77 of them.

We had difficulties at measuring tree-rings, because only in a part of the rim (e.g. *Fig. 8.18*) they were transversely cut. Less valuable wooden items are usually deep-frozen, the surface is smoothened with a very sharp blade and dried a bit before measuring tree-ring widths under a microscope. The wheel and the axle were unsuitable for such procedure, as we could not do any of the procedures listed above. In order to measure the tree-ring widths on the wheel, we smoothed a few centi-

[31] See Chapter 3 in this monograph: *Pl. 3.1*: 1,2.

[32] See Chapter 1 in this monograph.

[33] See Chapter 1.3 in this monograph.

[34] See Chapter 7 in this monograph.

[35] See Chapter 7 in this monograph.

8. PREHISTORIC WOODEN WHEEL WITH AN AXLE ...

Sl. 8.45: Fragment posode (glej poglavje 3 v tem zborniku: *t. 3.1:* 2), ki je ležal v sondi poleg osi (stran A2), med izkopavanjem J. Dirjeca. Foto: M. Turk.
Fig. 8.45: Pottery fragment (see Chapter 3 in this monograph: *Pl. 3.1*: 2), found in trench beside the axle (side A2), during excavation by J. Dirjec. Photo: M. Turk.

dogajanje na koliščarski naselbini v relativen časovni okvir. Ker so bile kronologije absolutno datirane z radiometrično metodo, smo s kombinacijo obeh metod konec naselbine datirali v leto 3109 ± 12 pr. Kr. oz. nekaj let po tem, in ugotovili, da je intenzivna poselitev pred tem letom trajala več kot 50 let.

Tudi za datiranje kolesa in osi je primerna uporaba obeh metod, torej dendrokronološke in radiometrične, ki pa imata tudi svoje omejitve, še posebno zato, ker smo želeli datirati samo dva kosa lesa različnih lesnih vrst. Ker smo pri osi lahko izmerili samo 44 branik, kar je premalo za zanesljivo datiranje, smo se posvetili predvsem analizi širin branik pri kolesu (deski A1), kjer smo izmerili 77 branik.

Težave so nastopile že pri merjenju branik, saj so te prečno prerezane le na delu oboda kolesa (npr. *sl. 8.18*). Kadar merimo arheološki les manj dragocenih predmetov, ga običajno najprej globoko zamrznemo, nato z zelo ostrim rezilom zgladimo površino in jo pred merjenjem širin branik pod mikroskopom še nekoliko osušimo. Tak

metres of wood. Measuring was done by hand, without a measuring table and a computer (*Fig. 8.46*). Annual rings were hardly visible due to unsuitable orientation and smoothing of wood, so a possibility of measuring errors was larger, while finding and correcting them is not easy without any comparative material and suitable reference curves.

When all the measurements were done, we cross-dated the obtained tree-ring series with all available tree-ring chronologies from the settlement at Stare gmajne and other settlements at the Ljubljansko barje. However, statistically significant cross-dating of the wheel was not obtained.

The Accelator Mass Spectometry procedure (AMS), which requires 1 g of dry weight of wood for its analyses, was chosen for radiocarbon (^{14}C) dating. C. 1 cm^3 large samples, with two annual rings each and 0.14 and 0.17 g of dry matter, were taken from the wheel and the axle (*Fig. 8.47*). The position of annual rings on samples and on the graph of tree-ring series were carefully noted.

Dendrochronologically registered samples of the wheel and the axle were sent to Vienna to the laboratory VERA – Vienna Environmental Research Accelerator [36] for radiocarbon dating. For radiocarbon dates see *Tab. 8.1.* The dates overlap with the age of the pile-dwelling settlement.[37] This confirms our assumption that the wheel was most probably made and used in the time of the younger period of the pile-dwelling settlement Stare gmajne.

8.6 CONCLUSION

Discovery of the wooden wheel and its axle at Stare gmajne is an important finding, not only in Slovenia but also in Europe and worldwide. As mentioned above, dating of the wheel and its axle overlaps with dating of the settlement, which suggests that the wheel and the axle were made and used contemporary with the existence of the settlement, during the younger settlement phase. Consequently, the wooden wheel is most probably c. 5150 years old[38] and it is among the oldest finds of this kind in Europe and worldwide.

Research showed that the find was produced by a top-level prehistoric wheelwright who had the knowledge of wood and its characteristics and knew how to make wheels and carts. Considering the quality of the discovered wheel, this is not the only product of this kind made by the skilled prehistoric master. Depictions of carts, pottery models, ruts and routes that were in good condition show, that the invention of a cart very

[36] Institut für Radiumforschung und Kernphysik der Universität Wien.
[37] See Chapter 7 in this monograph.
[38] Compare with Chapter 7 in this monograph.

Sl. 8.46: Ekipa dendrokronološkega laboratorija Oddelka za lesarstvo BF pri merjenju širin branik na kolesu; z leve: P. Cunder, K. Čufar in M. Zupančič. Foto: M. Turk.
Fig. 8.46: The team of the Dendrochronological laboratory of the Department of Wood Technology, Biotechnical Faculty, is measuring tree-ring widths on the wheel; from left: P. Cunder, K. Čufar and M. Zupančič. Photo: M. Turk.

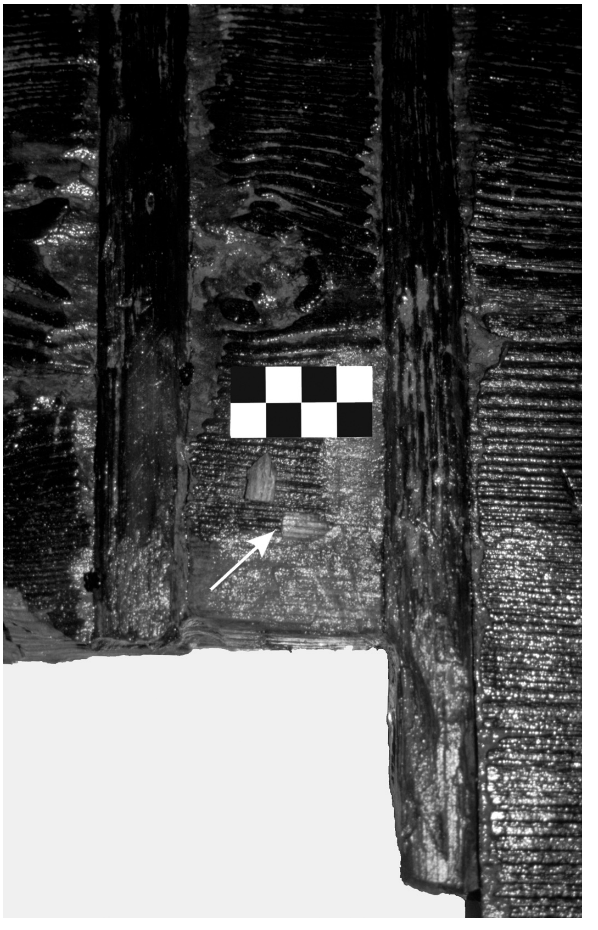
postopek pri kolesu in osi ni prišel v poštev, saj nismo mogli opraviti niti enega od naštetih korakov. Za merjenje širin branik pri kolesu smo na razdalji nekaj centimetrov nekoliko zgladili les. Merjenje smo opravili ročno, brez merilne mizice in računalnika (*sl. 8.46*). Ker so bile branike zaradi neustrezne orientacije in obdelave lesa slabo vidne, je bila večja verjetnost napak pri merjenju, njihovo iskanje in odprava pa sta brez primerjalnega materiala in ustreznih referenčnih krivulj težavna.

Ko so bile meritve opravljene, smo grafe sinhronizirali z vsemi razpoložljivimi kronologijami naselbine Stare gmajne in drugih naselbin na Ljubljanskem barju, vendar statistično zanesljivo relativno datiranje kolesa ni uspelo.

Za absolutno datacijo smo izbrali radiokarbonsko datiranje z metodo atomske masne spektroskopije (AMS), ki za analizo zahteva pod 1 g suhe snovi. Za datiranje smo iz kolesa (*sl. 8.47*) in osi odvzeli po 1 cm^3 velika vzorca, ki sta vsebovala po dve braniki in 0,14 oz. 0,17 g suhe snovi. Branike oz. njihovo lego na vzorcu oz. v grafu zaporedij širin branik smo prej natančno zabeležili.

Dendrokronološko protokolirana vzorca kolesa in osi smo poslali na radiokarbonsko datiranje na Dunaj v laboratorij VERA-Vienna Environmental Research Accelerator.[37] Radiokarbonski dataciji kolesa in osi sta podani v *tabeli 8.1*. Ugotovljena starost se ujema s starostjo koliščarske naselbine.[38] S tem je potrjena naša domneva, da je bilo kolo najverjetneje narejeno in uporabljano v času mlajšega dela koliščarske naselbine Stare gmajne.

[37] Institut für Radiumforschung und Kernphysik der Universität Wien.
[38] Glej poglavje 7 v tem zborniku.



Sl. 8.47: Kolesna deska A1. Mesto vzorčenja za radiokarbonsko datiranje. Foto: M. Turk.
Fig. 8.47: Wheel plate A1. Area of sampling for radiocarbon dating. Photo: M. Turk.

probably occurred some centuries before the wheel of Stare gmajne was made. However, the question whether it was invented in Mesopotamia or one or several places in Europe, stays unanswered.[39]

Nevertheless, the most important value of this find is that it is technologically advanced, above all, due to selection of wood, use, orientation and processing of the wood.

The hub is rectangular, which indicates that the wheel and its axle turned simultaneously. This is particularly suitable undercarriage of a two-wheeled cart[40] or a handcart. Similar finds are known from hilly areas of Central Europe (e.g. Switzerland and south-western Germany). Four-wheeled carts with fixed axles and circular hubs were used on European plains at that time. The latter indicates that four-wheeled carts were more

[39] See Schlichtherle 2006, 173–176.
[40] Schlichtherle 2006, 168–170.

Tab. 8.1: Radiokarbonski dataciji kolesa in osi. Datiranje je bilo opravljeno v dunajskem laboratoriju Vienna Environmental Research Accelerator pri Institut für Radiumforschung und Kernphysik der Universität Wien.
Tab. 8.1: Radiocarbon dates of the wheel and the axle. Dating was performed in the laboratory Vienna Environmental Research Accelerator at the Institut für Radiumforschung und Kernphysik der Universität Wien/Vienna.

Predmet Object	**Lab. št. Lab. Nr.**	**$\delta^{13}C$*) [‰]**	**^{14}C-age* [BP]**	**Kalibrirana starost ** Calibrated age ****
Kolo / Wheel	VERA-2560	–24,4 ± 2,6	4480 ± 25	3340 BC (90,0 %) 3080 BC 3070 BC (5,4 %) 3030 BC
Os / Axle	VERA-2561	–26,2 ± 0,6	4530 ± 35	3360 BC (95,4 %) 3090 BC

* 1σ – napaka / error
** Datum, določen z uporabo kalibracijskega programa OxCal v okvirju 2σ standardne napake, verjetnost posamezne datacije je označena v oklepaju. / Determined with the calibration program OxCal, data correspond to the 2σ – confidence level, probability of the individual time periods in brackets.

8.6 SKLEP

Najdba lesenega kolesa in osi na Starih gmajnah je zagotovo pomembno odkritje ne le v slovenskem, temveč tudi evropskem oz. svetovnem merilu. Kot že rečeno, se datiranje kolesa in osi ujema s starostjo naselbine, kar nakazuje, da sta bila kolo in os narejena in uporabljana v času njenega obstoja, in to v obdobju njene mlajše poselitvene faze. Po teh ugotovitvah je leseno kolo najverjetneje staro približno 5150 let,[39] kar ga uvršča med najstarejše najdbe te vrste v Evropi in na svetu.

Raziskava je pokazala, da je najdbo naredil vrhunski prazgodovinski kolar, ki se je odlično spoznal na les, na njegove lastnosti ter tudi na izdelovanje koles in vozov. Glede na kakovost izdelave menimo, da kolo, ki smo ga našli, ni edini izdelek te vrste, ki ga je naredil prazgodovinski mojster. Upodobitve vozov, keramični modeli, kolesnice in urejene poti kažejo, da je do iznajdbe voza zelo verjetno prišlo nekaj stoletij pred izdelavo kolesa na Starih gmajnah. Ob tem vprašanje ostaja, ali v Mezopotamiji ali na enem ali več mestih v Evropi, še odprto.[40]

Kakor koli že, največja vrednost naše najdbe je njena tehniška dovršenost. Pri tem imamo v mislih predvsem izbiro lesa, njegovo uporabo, orientacijo in obdelavo.

Pesto je štirikotne oblike, kar kaže, da sta se kolo in os vrtela sočasno in da gre za rešitev, ki je primerna predvsem za podvozje dvokolesnega voza[41] oz. neke vrste cize. Najdbe podobnih koles in osi poznamo s hribovitih območij Srednje Evrope (npr. Švice in jugozahodne Nemčije). Ravninska Evropa tistega časa pa pozna štirikolesne vozove z nepremično osjo in pestom okrogle oblike v kolesu. Slednje je raziskovalce napeljalo na misel, da so bili štirikolesni vozovi primernejši za ravninske predele, dvokolesniki pa za uporabo v hribovitem svetu.[42]

Morda se zdi nenavadno, da smo na dele podvozja prazgodovinskega voza naleteli na kolišču Stare

[39] Prim. s poglavjem 7 v tem zborniku.
[40] Glej Schlichtherle 2006, 173–176.
[41] Schlichtherle 2006, 168–170.
[42] Npr. Schlichtherle 2002, sl. 30.

suitable for flat terrain, while two-wheeled carts were the most suitable types for a hilly land.[41]

It perhaps seems unlikely that the undercarriage of a prehistoric cart was found at the Stare gmajne pile-dwelling at the Ljubljansko barje, as it is assumed that during the second half of the 4th millennium BC lake still existed.[42] Lake and cart do not interconnect somehow. However, we think that this is not the case at Stare gmajne. Furthermore, it seems important that we came across an undercarriage of, most probably, two-wheeler. Namely, the pile-dwelling settlement is located c. 700 m from the dry riverbank and was very probably erected in marsh next to the lake.[43] Wooden tracks were perhaps connecting it with a dry land. Wooden tracks have not yet been found at the Ljubljansko barje, but they are known elsewhere in Europe.[44]

Lake and marsh, in some areas, were covering a large area of plain, which is since the 19th century known as the Ljubljansko barje. Only hills in the hinterland, which are also the main geographical feature of central Slovenia,[45] stayed dry, and use of a two-wheeled cart seems logical in such a region.

[41] E.g. Schlichtherle 2002, Fig. 40.
[42] E.g. Pavšič 1989; Velušček 2007; Velušček, Čufar 2008.
[43] See Chapters 2 and 3 in this monograph.
[44] E.g. Burmeister 2002; 2006; Hafner 2002; Heumüller 2002.
[45] See Perko, Orožen Adamič 2001.

gmajne na Ljubljanskem barju, kjer naj bi po teoriji v drugi polovici 4. tisočletja pr. Kr. še vedno bilo jezero.[43] Jezero in voz nekako ne gresta skupaj. Menimo, da v primeru najdbe s Starih gmajn vendarle ni tako. Še več, pomembno se zdi, da smo naleteli na podvozje zelo verjetno dvokolesnega voza. Koliščarska naselbina namreč leži približno 700 m od trdinskega brega in je bila zelo verjetno postavljena v močvirju ob jezeru.[44] S trdino so jo morda povezovale poti iz okroglic, oblic, plohov ali mostovži. Na Ljubljanskem barju takšne vrste poti sicer še nismo našli, poznamo pa jih z drugih območij Evrope.[45]

Jezero oz. na nekaterih območjih že močvirje je torej prekrivalo velik del ravnine, ki jo od 19. stoletja poznamo kot Ljubljansko barje. Kot trdinski svet je v zaledju koliščarjem preostalo v glavnem samo hribovje, kar je tudi glavna geografska značilnost osrednje Slovenije,[46] in v takšni pokrajini se zdi, kot omenjeno, uporaba dvokolesnega voza smiselna.

[43] Prim. Pavšič 1989; Velušček 2007; Velušček, Čufar 2008.

[44] Glej poglavji 2 in 3 v tem zborniku.

[45] Npr. Burmeister 2002; 2006; Hafner 2002; Heumüller 2002.

[46] Glej Perko, Orožen Adamič 2001.